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June, 1930

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JOURNAL

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AMERICAN WELDING SOCIETY

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AMERICAN WELDING SOCIETY
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President E. A. Doyle

Actively identified with the welding industry for the past fourteen years, E. A. Doyle, recently elected president of the American Welding Society, first became interested in this profession in 1908, when he took part in the cutting operations incident to raising the battleship Maine from Havana harbor. Subsequently, other engineering activities occupied his time, but in 1916 he resumed his contact with the industry, entering the Davis-

PRESIDENT E. A. DOYLE

Bournonville Company's trade school at Jersey City, N. J., to learn the fundamental principles of oxy-acetylene welding and cutting. Later he became a salesman for this company.

During the World War, he served in the United States Army Corps of Engineers, starting with the rank of first lieutenant and rising to the rank of major. Returning to the Davis-Bournonville Company in 1919 as works manager, he subsequently became gerenal manager. In March, 1922, Mr. Doyle joined The Linde Air Products Company as assistant general sales manager in charge of service. Four years later he became consulting engineer in charge of process development.

Mr. Doyle has been prominently identified with the activities of the American Welding Society since its formation. He served as a director and was responsible for the organization of the Committee on Building Codes, of which he was chairman until his election to the presidency. He is a charter member of the Society of American Military Engineers, and of several other technical and scientific organizations, and until his resignation a year ago, was a major in the Engineer Reserve Corps, in charge of production in the New York Procurement District.

Qualifying Welders

Reprinted from May 1, 1930, issue of *Engineering News-Record.*

Proof, if proof were needed, of the efficacy of qualification tests for welders was furnished convincingly by the progress report of the structural steel welding committee at the convention of the American Welding Society last week. Plotted values of ultimate strengths of more than 1000 welded joints of various types and sizes made by welders in some 40 widely separated fabricating shops appeared as large black spots on the charts, so close was their agreement. Also, no striking difference was apparent between gas- and arc-welded specimens. This gratifying uniformity can be ascribed to no single factor more than to the qualifying tests which each welder was periodically required to pass. Briefly, these tests involved making test coupons by both horizontal and vertical welding which should average 45,000 lb. per square inch breaking strength in the weld metal. The actual average for the 33

welders who qualified, all of them run-of-shop welders, was 54,000 lb. To the engineer who desires to use welding but is held back by the fear that the human element cannot be eliminated, with certainty, the uniformity of these test results should prove a great satisfaction. The men who made the welds were kept on the alert by the qualification tests. There is no reason to believe that the same alertness and efficiency should not be capable of being developed on all routine or special shop and field work. If this is true, qualification tests, carefully and periodically administered, should lend assurance to the engineer who designs the structure and to the contractor who fabricates and erects it. Indeed, welding contractors might give some thought to devising a system of qualification certificates.

F. P. McKibben Elected Vice-Pres. of American Welding Society

Professor F. P. McKibben the newly elected Vice-President of the American Welding Society was born on Nov. 13, 1871, at Ft. Smith, Kansas, and graduated from the Civil Engineering Department of the Massachusetts Institute of Technology in 1894.

During the past two years, Prof. McKibben has become well known to the welding industry, having addressed 85 meetings of engineers and architects on the subject of welding steel buildings. The total attendance at these meetings was over thirteen thousand persons.

From 1894 to 1907 he served as instructor and professor in the Institute of Technology, and from 1907 to 1919 as Professor of Civil Engineering at Lehigh University, where he built the John Fritz Engineering Testing Laboratory.

From 1919 to 1926, Professor of Civil Engineering at Union College, Schenectady, N. Y., from which institution he resigned to devote all of his time to private practice.

During the thirty-two years of his connection with Colleges as Instructor and Professor of Structural Engineering, Mr. McKibben taught structural steel design and re-enforced concrete design. In addition to his teaching he has actively engaged throughout this period in engineering practice.

The following are some of the more important positions which Mr. McKibben held in the active practice of his profession:

Designing Engineer, Boston Elevated Ry Co., elevated railway structure and buildings; Assistant Bridge Engineer, Massachusetts Railroad

VICE-PRESIDENT F. P. MCKIBBEN

Commission; made calculations for and examined 1500 railroad bridges and 800 highway bridges during six years; designed, equipped, and for ten years had charge of operation of Fritz Testing Laboratory at Bethlehem, Pa., testing steel and concrete, etc.; Consulting Engineer, Pennsylvania Water Supply Commission 1914; bridges and dams; one of the organizers of People's Trust Co., Bethlehem, Pa., and Vice-President for five years; was connected with the design of the following structures: Connecticut River Bridge at Chicopee, Mass.; Merrimac River Bridge at Haverhill, Mass.; Bridge at Gloucester, Mass.; Bridge at Beverly, Mass.; Twenty-three bridges in Western Massachusetts; Bridge in Central Park, Schenectady, N. Y.; New Bedford, Mass.; drawbridge with revolving weight of 2,000,000 lbs.; steel work for New Bedford Savings Bank, highway bridge over Allegheny River at Oil City, Pa.

In 1924 and 1925 Mr. McKibben was City Engineer of Schenectady, N. Y.; also serving as a member of the Planning Commission, of the Board of Estimate and Apportionment, of the Park Board, of the Board of Contract and Supply.

The Chapter on Steel Bridge Construction in the American Civil Engineers Handbook (first edition) and the chapter on Concrete Arch Bridges in Taylor & Thompson's Concrete—Plain and Re-enforced were written by Mr. McKibben.

He is at present Consulting Engineer for General Electric Co.; and for the City of Rochester where he is building two bridges. He also has charge of two fourteen-story welded buildings.

SECTION ACTIVITIES

Detroit

A joint meeting was held with the Society of Automotive Engineers on April 21. H. A. Woofter, of the Swift Electric Welder Company, gave an illustrated lecture on Resistance Welding in the Automotive Industry. After the paper on welding the annual dinner of the S.A.E. was held, followed by a description of the sixteen-cylinder Cadillac car by Mr. Strickland, chief engineer of the Cadillac Motor Car Company. About fifty people attended.

Northern New York

A very interesting meeting of this Section was held on June 12 at the Pittsfield Works of the General Electric Company. The program was as follows: At 2.30 p. m. an inspection trip to see the applications of welding in the Pittsfield Works; at 6.30 p. m. a chicken dinner, and at 8.00 p. m. the meeting, at which an illustrated lecture on gas welding was presented by Mr. Graw of the Air Reduction Sales Company, which included a demonstration of gas welding tubes. Sound motion picture films followed on Atomic Hydrogen Welding, Conquest of the Cascades and The Electric Ship.

Western New York

The regular monthly meeting of the Western New York Section was held at the Statler Hotel, Buffalo, N. Y., on May 26.

This meeting was devoted to Thermit Welding and was addressed by Robert L. Browne of the Metal & Thermit Corp. The very interesting and instructive lecture was illustrated by lantern slides and moving pictures. There was also an actual demonstration of this process of welding.

This is the last monthly meeting of this season and a complete program for the following season will soon be announced.

San Francisco

The May meeting of the San Francisco Section was held at the Athens Athletic Club, Oakland, Cal., on the 23rd.

The meeting was devoted to the subject: "Resistance Welding," with W. J. McRea as the principal speaker. Mr. McRea discussed butt, spot and seam welding and gave a general review of the industries in which this process finds its greatest use. A lively discussion followed the presentation of the paper.

Boston

A meeting of the Boston Section was held in the plant of the General Welding & Equipment Company on May 23. At this meeting was shown the latest developments in metal coating, atomic hydrogen welding, shape cutting machines and fabrication. Brief introductory remarks were given by Drs. Leopold Pessel, Metals Coating Company of America; S. Martin, Jr., General Electric Company, and A. Krebs, General Welding and Equipment Company. At the demonstration opportunity was provided for the asking of questions and discussion of points of interest. Refreshments were served.

New York

The regular monthly meeting of the New York Section was held on May 20. Commander Edward Ellsberg spoke on the "Development of the Ellsberg S-51 Underwater Cutting Torch." In connection with this paper a motion picture covering the activities in the raising of the U. S. S. S-51 was shown. Charles Kandel spoke on the "Industrial Projects on Which the Ellsberg Underwater Cutting Torch Has Been Used." This

was illustrated with stereopticon views. An exhibition of diving rig and complete underwater cutting outfit, including demonstration of dressing a diver for his work, followed the presentation of the papers.

SOME OF THE CONTRIBUTORS TO THIS ISSUE

L. H. Burkhart, author of the paper on "Welding of Super-Code Pressure Vessels," graduated from the Missouri State University in 1897. He has been connected with the welding industry for 22 years and has been chief engineer for the Struthers-Wells Company for the past 33 years. He is a member of the American Society of Mechanical Engineers and the American Welding Society and numerous technical committees of the American Welding Society, with particular reference to pressure vessels. He is author of several technical papers published for various engineering societies.

J. H. Edwards, chief engineer of the American Bridge Company, is joint author of the paper on "Transverse Tests of H-Section Column Splices." Mr. Edwards has served as director of the American Society of Civil Engineers, trustee of Cornell University, and has been conspicuously identified with the welding industry through his pioneer work in the design and erection of welded steel structures. He was awarded the 1928 Samuel Wylie Miller Medal of the American Welding Society for his contribution to applications of welding in this field. He is chairman of the Structural Steel Welding Committee of the American Bureau of Welding.

H. L. Fetter, manager of the Rochester Welding Works, author of the paper on "Job Shop Welding," was born in 1890. He was assistant general foreman and regional inspector for the Pennsylvania Railroad, but left their service in 1921 to become superintendent of the Rochester Welding Works, in which connection he was associated with the late S. W. Miller. He is a member of the American Welding Society, Rochester Engineering Society and the Rochester Chamber of Commerce.

A. H. Stang, senior materials engineer of the U. S. Bureau of Standards, joint author of the paper on "Transverse Tests of H-Section Column Splices," was born in 1889. He has been connected with the Engineering Mechanics Section of the Bureau since 1919. He is author of several Bureau technologic and research papers giving results of investigations on various engineering materials. He is a member of the American Society for Testing Materials and the American Physical Society.

Herbert L. Whittemore, chief, Engineering Mechanics Section, Bureau of Standards, joint author of the paper on "Transverse Tests of H-Section Column Splices," was born in 1876, and graduated from the University of Wisconsin in 1903. He has had practical experience in several shops in the East and Middle West and developed methods of production in Berlin, Germany, Manchester, England, and New Hampshire, U. S. A. He was in charge of the student instruction and materials laboratory, University of Illinois, in 1910, and engineer of tests at the Watertown Arsenal from 1910 to 1912. He taught engineering mechanics in several universities, including Columbia and Oklahoma. He has been connected with the Bureau of Standards since 1917, and was awarded the Morehead Medal of the International Acetylene Association for 1927 for outstanding research work relating to industrial applications of oxy-acetylene welding.

SERVICES AVAILABLE

A-101. Electric Arc Welder of high caliber desires position with reliable firm or industry. Must be permanent. General Electric Arc Welding School trained and ten years' practical experience.

A-102. Structural Engineer now Sales Manager of well-known manufacturer of structural steel and ornamental iron, using considerable arc welding, desires to form a connection with a manufacturer specializing in, or wishing to specialize, in the manufacture and erection of structural steel and ornamental iron by welding methods. Would desire to make some investment.

A-103. Welder desires position. Just recently completed a course in electric and acetylene welding. Would prefer electric welding but is willing to do either.

Transverse Tests of H-Section Column Splices*

By James H. Edwards[1], H. L. Whittemore[2], and A. H. Stang[3]

I. INTRODUCTION

Steel structures are composed of large members, such as columns and floor beams, joined or fastened together with small plates, angles, or other shapes which are commonly referred to as structural details. The complex distribution of stress in the details requires that tests be made to show whether the methods used in determining the size of the details result in safe and economical structures. If for some reason a detail is changed, further tests should be made to determine the effect of the change.

The adoption of welding in the fabrication and erection of structural steel has brought about the modification of many structural details. The present investigation was undertaken to determine the effect of substituting welding for riveting in the fabrication of details used in splicing columns of steel-frame buildings and of changing the location of the splice plates from a position parallel to the flanges of the columns to one parallel to the webs of the columns.

The columns of steel-frame buildings are commonly made in 2-story lengths and are connected at alternate floors by splices. The weight of the structure and its contents and the wind pressure against the structure produce compressive, bending, and shearing stresses in the columns and splices. At the column connections or joints, the splice plates joining the ends of the columns resist the bending and shearing stresses. The compressive stress at the joints is commonly assumed to be carried by the columns only. The stress is transferred from the upper to the lower column by bearing.

The tests reported in this paper were made to investigate the strength and other properties of welded splice connections of H sections subjected to bending. No tests were made to determine the resistance of this type of connection to shearing stresses.

Columns in steel-frame buildings are commonly 10, 12 or 14 in. wide. Data on the strength of splices of these sizes of columns were desired, using as few specimens as possible. As wind pressure on a building may produce loads on the columns in the direction of either of the transverse axes, it was necessary to test some specimens under loads parallel to one axis and other specimens under loads parallel to the other axis.

Because the specimens were loaded as simple beams, they will be called "beams" in this report. It should be remembered, however, that they represent spliced column sections under the action of bending stresses.

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[1] Chief engineer, American Bridge Company.
[2] Principal mechanical engineer, Bureau of Standards.
[3] Engineer, Bureau of Standards.
*Reprinted from Bureau of Standards Journal of Research, Vol. 4, March 1930.

The American Bridge Co. furnished the specimens which were designed by James H. Edwards, chief engineer. O. E. Hovey, assistant chief engineer, and other members of the company's engineering staff assisted in making the tests. Prof. Elmer O. Bergman, research associate, contributed considerably to the analysis of the test data and edited the manuscript.

TABLE OF SYMBOLS

B_U = Force exerted by upper bolts on plate.
B_L = Force exerted by lower bolts on plate.
C = Resultant compressive force.
T = Resultant tensile force.
$N.\ A.$ = Neutral axis.
C_1 = Compressive force on upper flange of H beam at spliced section.
C_2 = Resultant of B_U and C_1.
C_3 = Resultant of W_U and C_1.
W_U = Force exerted through upper weld on H beam.
W_L = Force exerted through the lower weld on H beam.
S_t = Tensile stress.
S_c = Compressive stress.
S_s = Shear stress in bolts.
S_{sw} = Shear force per unit length in weld.

II. SPECIMENS

Plates were placed parallel to the webs of the H sections and welded to the inside faces of the flanges as shown at *A* in Fig. 1. The welds for the 10 and 14 in. H sections with the exception of column C14-B3B2W, which had fillet welds, were single-bevel butt welds as shown in Figs. 2 and 3. The welds for the 12-in. H sections were 5/16-in. fillet welds as shown in Figs. 4 and 5. The distance from the ends of the plates to the ends of the H sections were ½ in. The angles welded to the H section at *B* in Fig. 1 were used in an investigation of the strength of welded shelf angles which will be reported in a later paper.

The H sections were 3 ft. long and 10, 12, or 14 in. wide. They were fastened together in pairs with either two or four splice plates bolted to the plates which had been welded to the H sections. The bolts were ⅞ in. in diameter and were placed in two rows parellel to the longitudinal axes of the H sections. The plates had 15/16-in. punched holes. One splice plate was placed outside the welded plates on each side of the specimens that had single splice plates. (Fig. 2 to 6.) Two splice plates, one inside and one outside the welded plates, were used on each side of the specimens that had double splice plates. (Fig. 7.)

The properties and dimensions of the specimens are given in Table 1. Fig. 7 shows a specimen in the machine before testing. The cross sections of the specimens are given in Figs. 2 to 5. The dimensions of the H sections are the nominal dimensions given in Carnegie Beam Sections (1st ed., 1927).

Four specimens were tested with the loads parallel to the splice plates and to the webs of the H sections as shown in Fig. 7. Two of these were composed of 10-in. H sections (Fig. 2), the other two were of 14-in. H sections (Fig. 3). One specimen of each size had single, the other had

double splice plates. The same H sections were used for the specimens with single and with double splice plates, the specimens with single plates being tested first. It was believed that the behavior of 12-in. specimens could be predicted with sufficient accuracy for design purposes from the data on the 10 and 14 in. specimens.

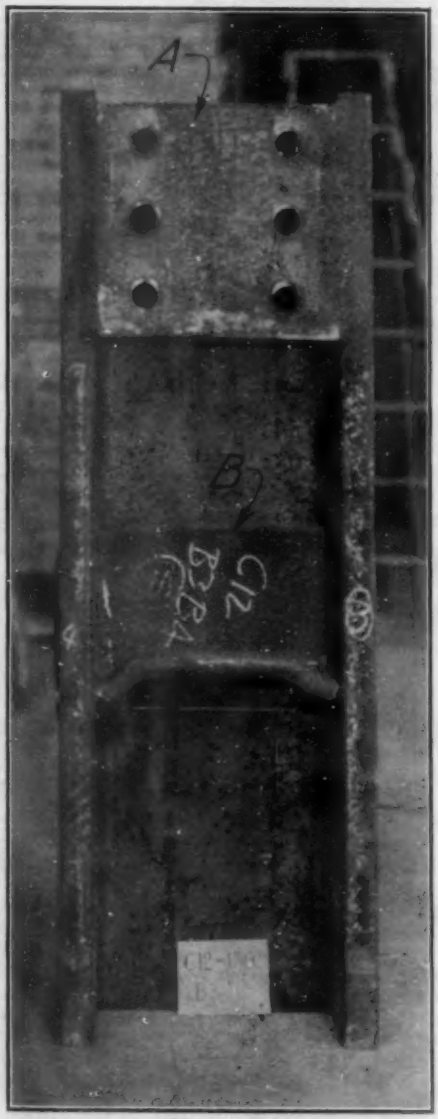


FIG. 1—H SECTION SHOWING PLATE WELDED TO INSIDE FACES OF FLANGES AT A

Three specimens were tested with loads perpendicular to the splice plates and webs as shown in Fig. 6. One specimen consisted of 12-in. H sections and single splice plates and one of 12-in. H sections and double splice plates. (Fig. 4.) Used in conjunction with the data from specimens with loads parallel to the splice plates, the results from these two

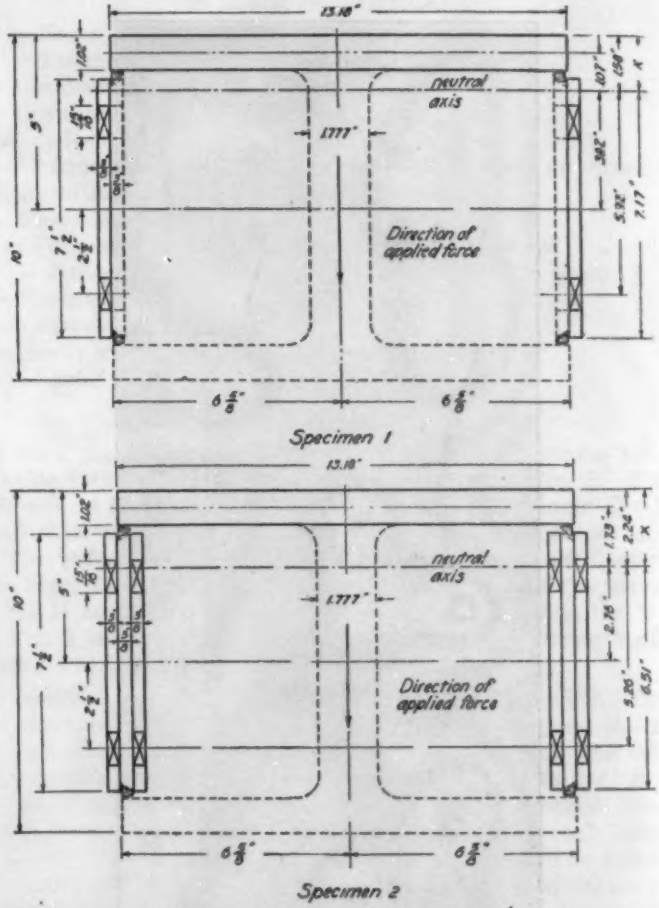


FIGURE 2.—*Specimen 1; column C10–B1B4; column C10–B2B4; single splice plates, SP1, load parallel to the web of the* H *sections. Specimen 2, column C10–B1B4, column C10–B2B4, double splice plates SP1, load parallel to the web of the* H *sections*

Cross section at splice of specimens with loads parallel to web, showing position of neutral axis. Portions carrying stress indicated by full lines.

specimens should give a good indication of the behavior of the 10 and 14 in. specimens under loads perpendicular to the splice plates. The third specimen in this group consisted of one 12-in. and one 14-in. H section with a bearing plate between and with single splice plates. (Fig. 5.) It

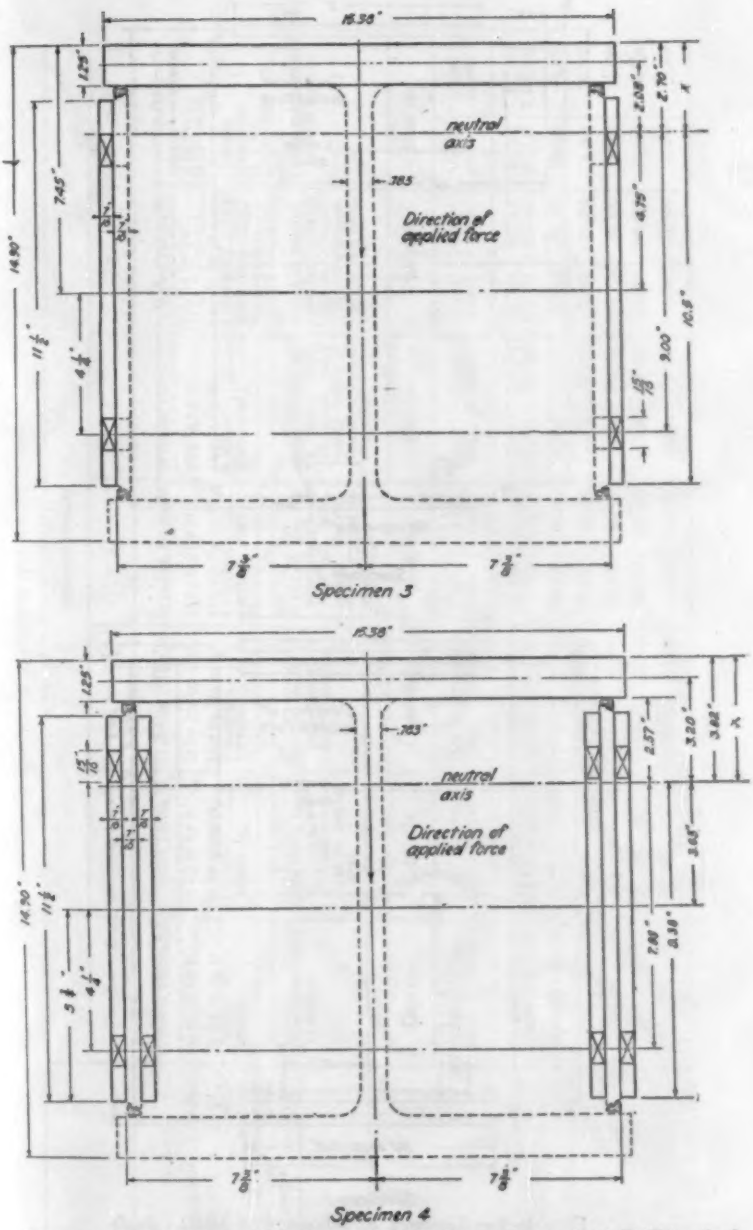


FIGURE 3.—*Specimen 3, column C14–B1B4, column C14–B2B4, single splice plates, SP3, load parallel to the web of the* H *sections. Specimen 4, column C14–B1B4, column C14–B2B4, double splice plates, SP3, load parallel to the web of the* H *sections*

Cross section at splice of specimens with loads parallel to web, showing position of neutral axis. Portions carrying stress indicated by full lines.

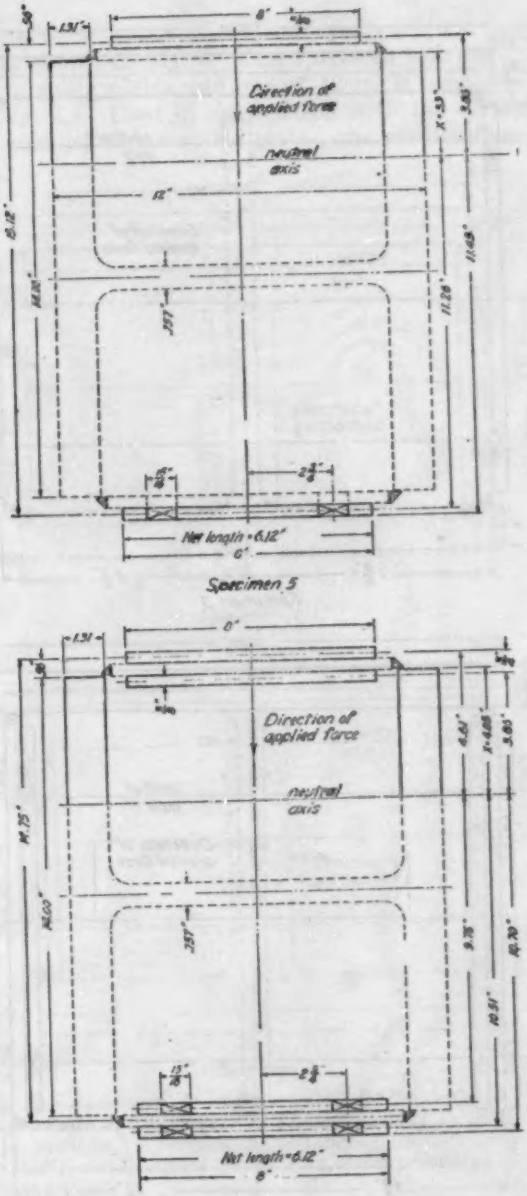


FIGURE 4.—*Specimen 5, column C12–B5B4, single splice plates, SP2; load perpendicular to web of the* H *sections. Specimen 6, column C12–B1B2W; column C12–B5B4, double splice plates, SP2; load perpendicular to the web of the* H *sections*

Cross section at splice of specimens with loads perpendicular to web, showing position of neutral axis. Portions carrying stress indicated by full lines.

TABLE 1.—*Dimensions of specimens and results of tests*

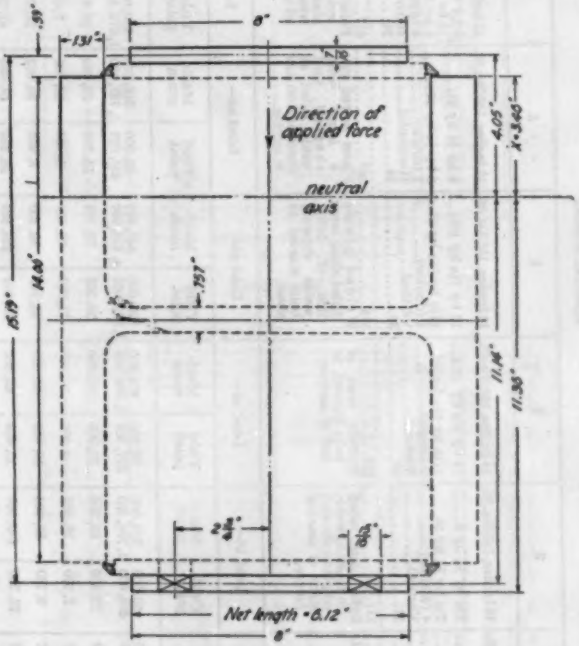
	Specimen number													
	1		2		3		4		5		6		7	
H section	10 inches, 140 lbs./ft.		10 inches, 140 lbs./ft.		14 inches, 165 lbs./ft.		14 inches, 165 lbs./ft.		12 inches, 150 lbs./ft.		12 inches, 150 lbs./ft.		(12 inches, 150 lbs./ft. 14 inches, 165 lbs./ft.	
Welded plates, size.....inches	7¾ by ⅜ by 9		7¾ by ⅜ by 9		12 by 7/16 by 12¼		12 by 7/16 by 12¼		9 by ⅜ by 9¼		(9 by ⅜ by 9¼ (12 by 7/16 by 9¼		12 by 7/16 by 9¼. 12 by 7/16 by 12¼.	
Splice plates, size.....do	7½ by ⅜ by 19		7½ by ⅜ by 19		11½ by 7/16 by 25		11½ by 7/16 by 25		8 by ⅜ by 19		8 by ⅜ by 19		8 by 7/16 by 27.	
Splice plates.....number	2 (single)		4 (double)		2 (single)		4 (double)		2 (single)		4 (double)		2 (single).	
Splice plates.....position	Vertical		Vertical		Vertical		Vertical		Horizontal		Horizontal		Horizontal.	
Bolts.....total number	24		24		32		32		24		24		32.	
Bearing plate, size.....inches													14½ by 2 by 15½.	
Moment of inertia.....in.⁴	84		141		357		583		367		617		427.	
Failure	Splice plates failed in tension.		Splice plates failed in tension, welded plates showed signs of bearing failure.		Bottom rows of bolts sheared, in one H section.		Welded plates failed along lower line of bolts, welds sheared, bolts started to shear.		Plates bowed up, 4 inner bolts sheared, and welds failed at inner end on one H section.		Failed in bearing, welded plate sheared lengthwise, welds opened up near ends.		Lower splice plate failed in tension.	
	Load at—		Load at—		Load at—		Load at—		Load at—		Load at—		Load at—	
	Yield point	Maximum	Yield point	Maximum	Yield point	Maximum	Yield point	Maximum	Yield point	Maximum	Yield point	Maximum	Yield point	Maximum
Load.....pounds	20,000	102,450	60,000	218,000	70,000	279,950	220,000	547,500	55,000	216,670	130,000	340,000	60,000	312,000
Bending moment.....lbs.-in.	247,500	845,200	495,000	1,798,500	577,500	2,300,600	1,815,000	4,516,900	453,800	1,787,500	1,072,500	2,805,000	495,000	2,574,000
Maximum tensile stress in splice plates.....lbs.-in.²	21,200	72,500	22,900	83,200	17,000	68,000	20,200	72,700	14,200	55,750	18,600	48,600	13,200	68,600
Maximum compressive stress in H section.....lbs.-in.²	4,700	16,000	7,900	28,600	4,400	17,500	11,900	29,550	4,100	16,100	7,000	18,400	4,000	20,900
Shearing stress in lower bolts.....lbs.-in.²	8,900	30,400	9,100	33,000	10,000	39,800	16,100	40,100	8,900	35,000	11,700	30,600	7,200	37,800
Bearing stress on lower bolts and plates.....lbs.-in.²	16,300	55,500	33,200	120,500	15,600	62,300	80,600	125,800	16,200	64,000	41,700	100,000	11,300	89,000
Shearing stress in lower welds.....pounds per linear inch	1,800	5,420	3,200	11,800	1,790	7,170	5,700	14,100	1,800	7,000	4,800	11,800	1,400	7,800

was included to show the effect of a difference in width of the H sections.

III. TEST PROCEDURE

1. *Loading of Specimens*

Specimens 1, 3, and 5 were tested in the bureau's 600,000-lb. capacity testing machine. Because of the larger loads required to produce failure, the other specimens were tested in the 10,000,000-lb. capacity machine. The specimens were tested as simple beams on a 66-in. span with loads applied at the quarter points.



Specimen 7

FIGURE 5.—*Specimen 7, column C14–B3B2W, column C12–B1B2W, bearing plate, C12F, between columns, single splice plates, SP4, load perpendicular to the web of the* H *sections*

Cross section at splice of specimens with loads perpendicular to web, showing position of neutral axis. Portions carrying stress indicated by full lines.

In the 600,000-lb. machine the specimen was placed on 2½-in. rollers which were free to roll so as to avoid axial constraint in the specimen. A loading beam rested on 2-in. rollers placed on the specimen at the quarter points. The spherical bearing block of the testing machine was applied to a 2-in. roller placed at the midspan of the loading beam.

The method of loading specimens in the 10,000,000-lb. machine is shown in Fig. 7. The pins in the end supports were 2½ in. in diameter and the

FIG. 6—SPECIMEN 7 AFTER TRANSVERSE TEST; 12-INCH AND 14-INCH H SECTION WITH BEARING PLATE, LOADS PERPENDICULAR TO WEB
Lower splice plate failed in tension

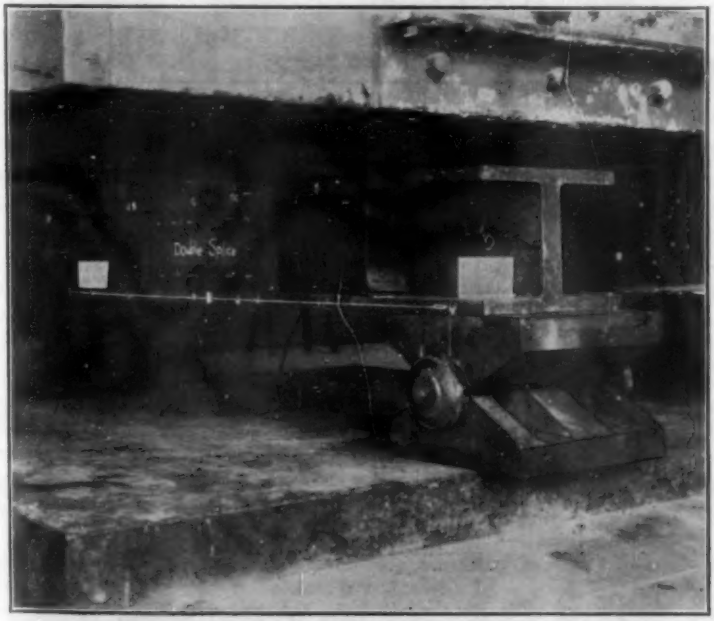


FIG. 7—SPECIMEN 2 BEFORE THE TRANSVERSE TEST; TWO 10-INCH H SECTIONS; LOADS PARALLEL TO WEB
Splice plates failed in tension; welded plates showed signs of bearing failure

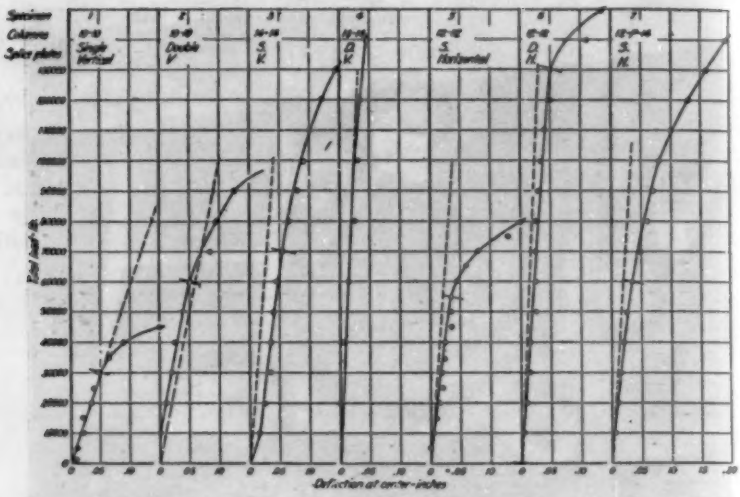


FIGURE 8.—*Load-deflection curves for spliced* H *sections, specimens 1–7.*

Full lines indicate measured deflection. Dash lines are deflection of a beam with similar loading having a constant moment of inertia equal to that computed for the weakest section of the test beam.

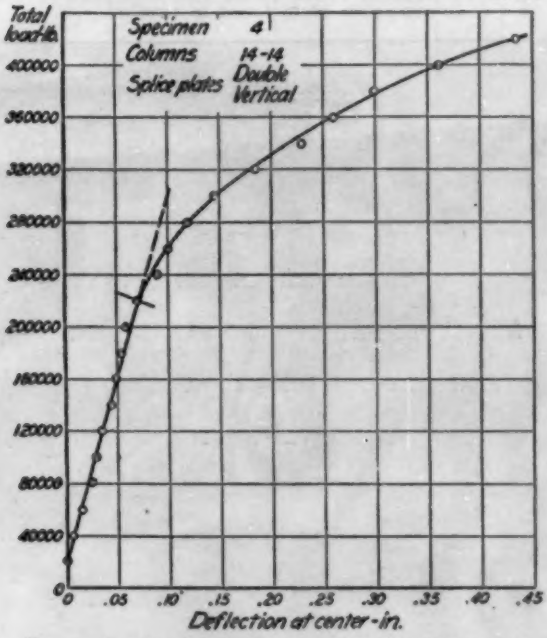


FIGURE 9.—*Load-deflection curve for spliced* H *sections, specimen 4, showing deflection at higher loads*

rollers at the quarter points of the specimen were 2 in. in diameter. The lower platen of the testing machine has a spherical bearing which was adjusted at the beginning of a test to produce equal bearing on the rollers on the top of the specimen. No provision was made to eliminate axial constraint in these specimens. It was decided that the expense of providing the required number of rollers to permit longitudinal movement was not justified.

2. *Measurement of Deflection*

Wires were stretched on each side of the specimens between points directly over the supports as shown in Fig. 7. The deflections of the specimens were obtained by observing the positions of the wires in a mirror having a scale attached. The scale was graduated in tenths of an inch and the deflection was read by estimation to the nearest hundredth of an inch. Readings were taken at 5000-lb increments of load for specimens 1 and 5, and at 10,000-lb. increments for the others.

IV. TEST RESULTS

The load-deflection curves for the specimens are shown in Fig. 8. Fig. 9 gives the curve for specimen 4 plotted to a scale which allows the deflection at higher loads to be shown. The cross lines on the curves of Figs. 8 and 9 are placed at the loads for which the deflection ceased to web. The splice plates failed in tension across the net section through "yield point" loads. The maximum load for each specimen is also given in Table 1. The meaning of the dash lines in Figs. 8 and 9 will be explained later.

A detailed account of the behavior of the specimens follows:

Specimen 1.—Ten-inch H sections, single splice plates, loads parallel to be proportional to the loads, and these values are listed in Table 1 as one of the groups of holes nearest the middle of the plate. The failure began at the lower edges of the plates and extended progressively to the upper holes. The failure was similar to that shown in Fig. 10.

Specimen 2.—Ten-inch H sections, double splice plates, loads parallel to web. Fig. 7 shows the specimen before testing, and Fig. 10 shows it after testing. This specimen failed in the same way that specimen 1 did. The lower holes in the welded plates were badly deformed.

Specimen 3.—Fourteen-inch H sections, single splice plates, loads parallel to web. The splice plates scaled at a load of 218,000 lb. The eight lower bolts in one of the H sections sheared.

Specimen 4.—Fourteen-inch H sections, double splice plates, loads parallel to web. Fig. 11 shows the specimen after test with the splice plates in place, and Fig. 12 shows it with one outer splice plate removed. The welded plates failed in bearing against the bolts. The holes elongated noticeably and one plate split between holes. The top and bottom welds of one plate on one side of the specimen failed. On the other side of the specimen the top weld of one plate and the bottom weld of the other failed. These weld failures occurred after the maximum load on the specimen had been reached. The lower rows of bolts started to shear. The webs of the H sections over the supports scaled, and the H sections were permanently bent and distorted.

FIG. 10—SPECIMEN 2 AFTER TRANSVERSE TEST; 10-INCH H SECTIONS; DOUBLE SPLICE PLATES; LOADS PARALLEL TO WEB OF H SECTION
Splice plates failed in tension. Specimen 1 failed in a similar way

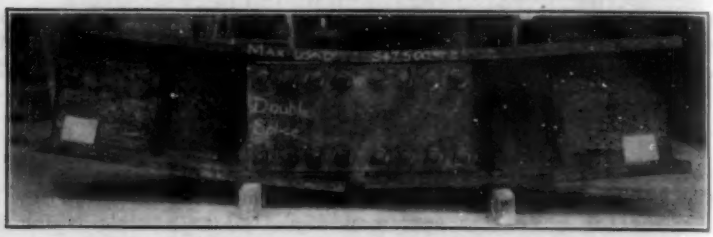


FIG. 11—SPECIMEN 4 AFTER TRANSVERSE TEST; 14-INCH H SECTIONS; DOUBLE SPLICE PLATES; LOADS PARALLEL TO WEB

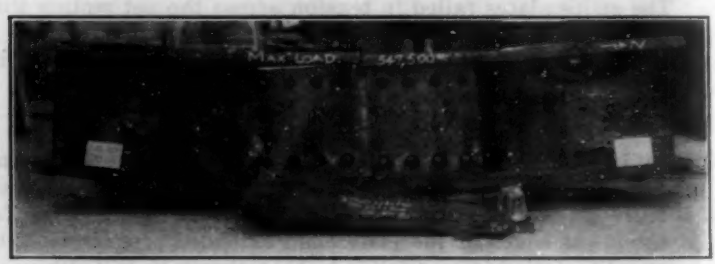


FIG. 12—SPECIMEN 4 AFTER TRANSVERSE TEST WITH OUTSIDE SPLICE PLATES REMOVED; 14-INCH H SECTIONS; DOUBLE SPLICE PLATES; LOADS PARALLEL TO WEB
Welded plates failed along lower line of bolts; welds sheared; bolts started to shear

FIG. 13—SPECIMEN 6 AFTER TRANSVERSE TEST WITH LOWER SPLICE PLATE REMOVED; 12-INCH H SECTIONS; DOUBLE SPLICE PLATES; LOADS PERPENDICULAR TO WEB
Welded plates failed in bearing on bolts and sheared lengthwise; welds failed near ends

Specimen 5.—Twelve-inch H sections, single splice plates, loads perpendicular to web. The welded plates and the splice plate on the lower side of the specimen deformed, as the deflection increased, so that the longitudinal axis of the plates approached the webs of the H sections. The welds in one of the H sections sheared for a length of 3 in. beginning at the inner end of the welded plate. The four bolts nearest the middle of the joint in this H section sheared.

Specimen 6.—Twelve-inch H sections, double splice plates, loads perpendicular to web. Fig. 13 shows the specimen after test with the bottom splice plate removed. Only one H section from specimen 5 could be used in this specimen as the lower welded plate of the other sheared. The 12-in. H section from specimen 7 was substituted. The welded plates on this section were longer and thicker and had two addtional holes.

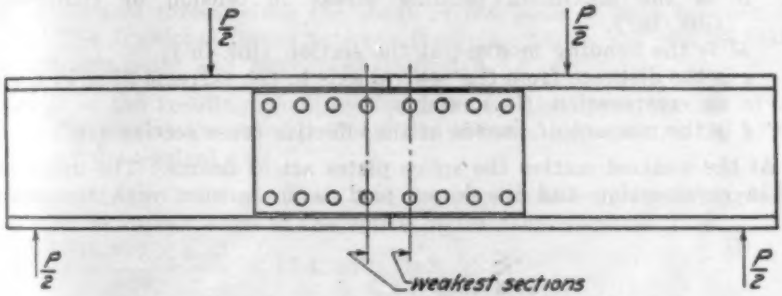


FIGURE 14.—*Diagram showing forces acting on the beam*

Since the splice plates were symmetrical, these two extra holes were not used. The thinner welded plate on the lower side of the specimen failed in bearing against the bolts. The holes elongated and the plate sheared between the holes. The welds failed for a short distance beginning at the outer end of the plate. All the lower bolts started to shear.

Specimen 7.—Twelve-inch and 14-in. H sections, single splice plates, loads perpendicular to web, bearing plate between ends of H sections. Fig. 6 shows the specimen after failure. The lower splice plate failed in tension on the net section through the holes nearest the end of the 14-in. H section.

A brief summary of the way in which the specimens failed is given in Table 1.

V. ANALYSIS OF DATA

1. *Stress*

The stresses in the specimens were computed using the common or Euler-Bernoulli theory of beams. Although the use of this theory for these specimens is open to a number of objections which will be discussed later, the data at hand did not warrant the use of a more refined theory. The computed stresses in the different parts of the specimens are given in Table 1. The analysis of stress will be explained for specimen 4 to show how the computations are made.

With equal loads applied at the quarter points of the beam as shown in Fig. 7 and 14, the bending moment is constant between the loads and equals the product of one-half the total load and one-fourth of the length of the span. The maximum bending stresses occur at the section through one of the group of holes nearest the middle of the span. (Fig. 14.) Here the H sections are not effective in carrying tensile stress and the area of the splice plates is reduced because of the bolt holes. This section will be referred to as the "weakest section" of the beam.

The maximum bending stress in the splice plates and the H sections at the weakest section of the beam is given by the formula

$$S = \frac{Mc}{I} \qquad (1)$$

in which

S is the maximum bending stress in tension or compression (lbs./in.^{2}),
M is the bending moment at the section (lbs.-in.),
c is the distance from the neutral axis to the extreme fiber in tension or compression (in.), and
I is the moment of inertia of the effective cross section (in.^{4})

At the weakest section the splice plates act as beams. The upper part is in compression and the lower part is in tension with the neutral

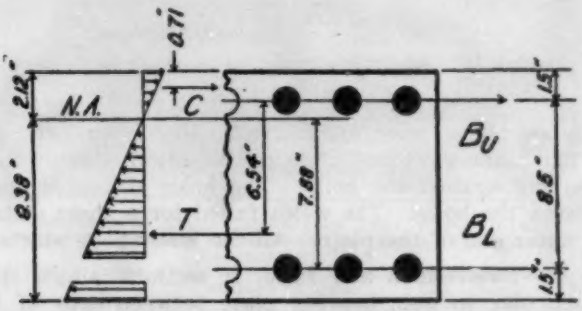


FIGURE 15.—*Free-body diagram showing forces acting on a splice plate*

axis as the line of zero stress. The H section does not here act as a beam since there is no way in which it can carry tensile stress. The compressive stress varies from a maximum in the outer fibers to zero along some axis lower in the H section. The gravity axis of the areas assumed to carry stress was taken as the neutral axis. Included in the area effective for carrying compressive stress is a small portion of the web of the H section lying between the neutral axis and the upper flange. Its effect on the position of the neutral axis and the value of the moment of inertia is small. Its effect on stress values is less than 2 per cent. Because of the shorter and simpler computations which resulted, this area has been neglected.

The portions of the specimens which are assumed to carry stress at the weakest section are shown by full lines in Fig. 2 to 5. The portions above the neutral axis are in compression and those below the neutral axis are in tension. The portions indicated by dash lines do not carry stress at the weakest section. The area of the bolt holes was deducted for all splice plates except the upper plates on specimens 5, 6, and 7.

After computing the location of the neutral axis (gravity axis), the magnitude of the moments of inertia and the maximum tensile and compressive stresses, the reactions between the splice plates and the bolts must be determined before the stresses in the bolts can be obtained. For the specimens having the splice plates vertical, Fig. 15 shows the part of the splice plates on one side of a section through the inner group of bolt holes and also the forces acting on it. The forces are the stresses on the cut sections and the reactions of the bolts on the plates. There are no vertical forces, since the shear in the beam is zero between the loads. The frictional forces between the splice plates and welded plates are indeterminate and have been neglected.

Let C = the resultant compressive force on the upper portion of the plates. It acts at the third point of the distance between the top of the plate and the neutral axis.

In computing C, for specimen 4 at the maximum load, the compressive stress at the upper edge of the splice plates from formula 1 is

$$S_c = \frac{4{,}516{,}900 \times 2.12}{583} = 16{,}420 \text{ lbs./in.}^2$$

The average stress is $\frac{16{,}420}{2} = 8{,}210$ lbs./in.^{2}

The total area above the neutral axis for the four splice plates is $4 \times 7/16 \times 2.12 = 3.70$ sq. in.

$$C = 8{,}210 \times 3.70 = 30{,}400 \text{ lb.}$$

Let T = the resultant tensile force on the lower portion of the plates. The stress on the outer fiber has been found to be 72,700 lbs./in.^{2} The stress at the axis of the holes is then $72{,}700 \times \frac{7.88}{9.38} = 61{,}100$ lbs./in.^{2}

As no stress is transmitted across the portion of the section through the bolt holes, $T = \frac{1}{2} \times 72{,}700 \times 9.38 \times 4 \times \frac{7}{16} - 61{,}100 \times \frac{15}{16} \times 4 \times \frac{7}{16} = 496{,}800$ lb.

The arm of T about the neutral axis, as found by taking moments about the neutral axis, is:

$$\frac{\left[\left(\frac{72{,}700}{2} \times 9.38 \times \frac{7}{16} \times 4\right) \times \frac{2}{3} \times 9.38\right] - \left[\left(61{,}100 \times \frac{15}{16} \times \frac{7}{16} \times 4 \times 7.88\right) \times 7.88\right]}{496{,}800} = 5.92 \text{ inches.}$$

The reactions of the bolts, B_L and B_V, may now be found from the principles of statics for parallel forces. To find B_L take moments about the line of action of B_V.

The arm of T about $B_V = 5.92 + 0.62 = 6.54$ in.
The arm of $C = 1.50 - 0.71 = 0.79$ in.

$$\Sigma M = 0 \quad B_L \times 8.5 - 496{,}800 \times 6.54 - 30{,}400 \times 0.79 = 0.$$
$$B_L = 385{,}000 \text{ lb.}$$
$$\Sigma F = 0 \quad B_V + 30{,}400 + 385{,}000 - 496{,}800 = 0.$$
$$B_V = 81{,}400 \text{ lb.}$$

B_V, therefore, acts in the same direction as B_L and C.

There are eight bolts in double shear on each side of the joint so the area in shear is $16 \times 0.60 = 9.60$ in.^{2} The average shearing stress in the lower bolts is:

$$S_s = 385{,}000 \div 9.60 = 40{,}100 \text{ lbs./in.}^2$$

The area in bearing is $8 \times 7/8 \times 7/16 = 3.06$ in.^{2} The average bearing stress in the lower bolts and the welded plates in contact with these bolts is:

$$S_c = 385{,}000 \div 3.06 = 125{,}800 \text{ lbs./in.}^2$$

To determine the forces, W_L and W_V, acting on the welds, consider the welded plates shown in Fig. 16 in equilibrium under the known reactions of the bolts and the unknown forces acting at the welds. These forces are parallel and the values of the unknown forces may be found from the conditions that $\Sigma F = 0$ and $\Sigma M = 0$.

$$\Sigma M = 0 \quad W_L \times 12.40 - 385{,}000 \times 10.45 - 81{,}400 \times 1.95 = 0.$$
$$W_L = 337{,}300 \text{ lb.}$$
$$\Sigma F = 0 \quad W_V + 337{,}300 - 385{,}000 - 81{,}400 = 0.$$
$$W_V = 129{,}100 \text{ lb.}$$

The length of weld on both plates is $2 \times 12 = 24$ in. The average shearing stress in the lower welds is:

$$S_{sw} = 337.300 \div 24 = 14{,}100 \text{ lbs./lin. in.}$$

The computations for finding the stresses in the bolts and welds of specimens with loads parallel to the web are somewhat laborious.

An alternate method which involves one additional approximation may be used. It is shorter, and the results are probably as accurate as the data warrant.

The free-body diagram of a part of one H section together with the plates welded to it is shown in Fig. 17. The H section is assumed to be cut at a point between the ends of the welded plates and the applied load so that the bending moment at the cut section is equal to the constant moment in the middle half of the beam. The forces acting across the cut section are the bending stresses in the beam. These vary from zero at the neutral axis to a maximum at the extreme fiber. The compressive and the tensile forces may be replaced by their resultants C and T. These constitute a couple whose moment is equal to the bending moment in the beam. The other forces acting on the free body are the bolt reactions, B_V and B , and the reaction between the ends of the two H sections, C_1. If C_1 and B_V are replaced by their resultant C_2, a second

couple consisting of C_2 and B_L is obtained. This couple balances the couple consisting of C and T and, therefore, its value is also equal to the bending moment in the beam. By computing values for different positions of C_2 it has been found that C_2 may be assumed to act along the outside face of the upper flange for specimens similar to the ones included in these tests.

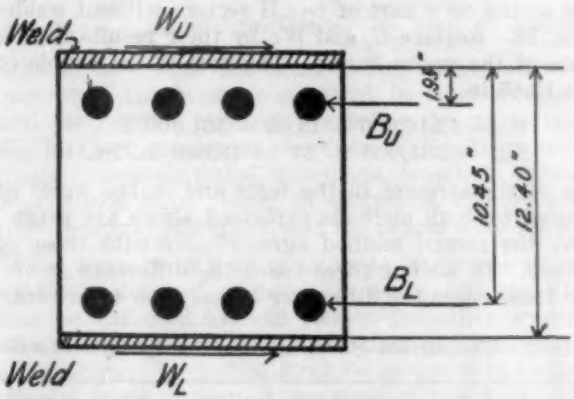


FIGURE 16.—*Free-body diagram showing forces acting on a welded plate*

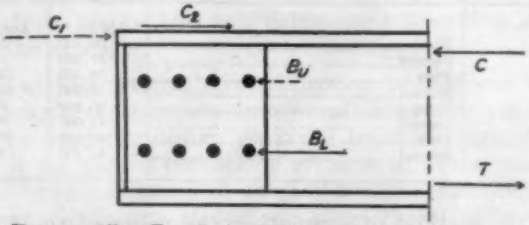


FIGURE 17.—*Free-body diagram showing forces acting on a welded plate and a portion of an H section*

C_2 is the resultant of C_1 and B_U.

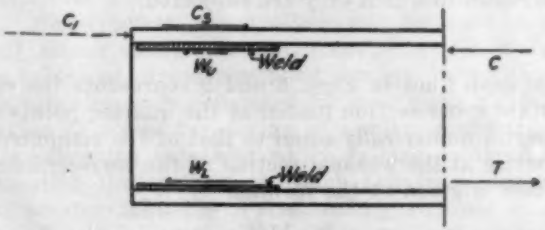


FIGURE 18.—*Free-body diagram showing forces acting on a portion of an H section*

C_2 is the resultant of C_1 and W_U.

The values of B_L may now be found by dividing the bending moment by the distance of B_L from the upper face of the specimen. For specimen 4, at the maximum load,

$B_L = 4{,}516{,}900 \div 11.70 = 386{,}000$ lb.
$S_s = 386{,}000 \div 9.60 = 40{,}200$ lb./in.^{2}
$S_c = 386{,}000 \div 3.06 = 126{,}200$ lb./in.^{2}

The forces acting on a part of one H section without welded plates are shown in Fig. 18. Replace C_1 and W_U by their resultant C_s acting along the outer face of the upper flange. The arm of the couple consisting of C_s and W_L is 13.65 in.

$W_L = 4{,}516{,}900 \div 13.65 = 331{,}000$ lb.
$S_w = 331{,}000 \div 24 = 13{,}800$ lb./lin. in.

The values of the stresses in the bolts and in the welds of specimens 1 to 4 computed by both methods explained above are given in Table 2. The values by the second method agree closely with those computed by the first method. In all but three cases the difference is on the side of safety and in these cases the difference is less than 4 per cent.

TABLE 2.—*Comparison of stresses computed by different methods*

Specimen	Method	Maximum shearing stress in lower row of bolts	Maximum bearing stress of lower bolts and plates	Maximum shearing stress in lower welds
		Lbs./in.^{2}	*Lbs./in.*^{2}	*Lbs./in.*^{2}
No. 1	First	30,400	55,500	5,420
	Second	31,300	57,300	5,290
No. 2	First	33,000	120,500	11,500
	Second	33,200	122,000	11,760
No. 3	First	39,800	62,300	7,170
	Second	41,000	64,200	7,050
No. 4	First	40,100	125,800	14,190
	Second	40,200	126,200	13,800

In general, the method of computing the value of the stresses in the specimens with loads perpendicular to the web are the same as those for the specimens with loads parallel to the web. (See specimen 5, Fig. 4.)

Dividing the total tension in the lower plate by the areas of the bolts in shear and in bearing and by the length of the welds in shear gives the average stresses to which they are subjected.

2. *Deflection*

Each of the dash lines in Figs. 8 and 9 represents the deflection of a beam of constant cross-section loaded at the quarter points and having a moment of inertia numerically equal to that of the computed value of the moment of inertia at the weakest section of the corresponding test beam.

This deflection is given by the formula

$$y = \frac{11Pl^3}{768EI}$$

in which y is the deflection at midspan (inches.)

P is the total load (pounds)
l is the span of the beam (inches)
E is the modulus of elasticity (lb./in.^{2}) and
I is the moment of inertia (in.^{4}).

VI. DISCUSSION

1. *Method of Analysis*

The formula, $S = \frac{Mc}{I}$, should preferably be used to compute bending stresses in a beam only when the beam is long compared with its cross-sectional dimensions, the beam is constant in cross-section throughout its length, and the bending stresses are below the proportional limit of the material. In these specimens the span of the beam was about five times the greatest cross-sectional dimension, which is below the values for which the common beam theory is applicable. There was a marked change in cross-section at the splice, and the beams were loaded to failure.

The use of the beam formula for ultimate loads was analogous to its use in finding the modulus of rupture. Stresses computed from the ultimate load may be expected to hold closely for other specimens of the same size, shape and loading, and approximately for those of similar size, shape and loading. They should not be used as a basis for the design of widely different types of connections without further test.

For abrupt changes of cross-section, such as occur in the neighborhood of the weakest section, there is no assurance that proportionality of stress to strain exists as was assumed in computing the bending stresses from their distance from the neutral axis determined according to the assumptions made in the anaylsis.

As the limit of proportionality of deflection to load was fairly definite for these specimens, the stresses corresponding to the "yield-point" loads can probably be used for design purposes because these stresses in the various parts of the spliced connection correspond to the maximum deflection to which the splice should be subjected. The stresses corresponding to the maximum loads are also given since these loads caused known changes in the specimens and the computed stresses serve as a criterion for determining the value of the analysis.

In developing a method of analysis which can be used in the design of details with complex stress distribution, assumptions such as these may give results that differ widely from the actual stress conditions in the specimen. Nevertheless, the analysis can be used in design if it gives values of stress which are consistent; that is, if for any type of failure the values of stress computed for specimens that failed are higher than those which were computed for specimens which did not fail. An ultimate value of stress for design of similar connections may then be set which is below the values at which failure occurred in the tests. In this investigation the stresses at which failure occurred were, with one exception, greater than the corresponding stresses at which there was no failure. For the exception, the difference in the value of stress is less than 5 per cent. Moreover, the computed values at which failure took place are equal to or slightly above the ultimate strength of struc-

tural steel in tension, shear, and bearing so that these ultimate values may be used in designing similar connections.

2. *Stress*

(a) H SECTIONS

The values of the compressive stresses in the H sections were low due to the short distance between the neutral axis and the extreme fibers.

(b) PLATES

Specimens 1, 2 and 7 failed by rupture of the splice plates in tension at computed stresses of from 68,600 to 83,200 lb./in.^{2} These computed stresses exceed the probable ultimate strength of the material in tension. A design based on an ultimate tensile strength of structural steel of 65,000 lb./in.^{2} with a proper factor of safety should result in a splice of adequate strength in tension.

In two other instances the plates did not have sufficient strength to resist the stress to which they were subjected. The plates in specimen 5 bowed up as has been explained. In specimen 6 one welded plate sheared lengthwise. Based on the net area of a section through the bolt holes the shearing stress in this plate was 45,800 lb./in.^{2} It is evident that in the design of a connection the strength of the plates should be computed to insure that they will not fail as in specimens 5 and 6.

(c) BOLTS

The bolts in specimen 3 sheared at a computed stress of 39,800 lb./in.^{2} In specimen 4, in which the splice plates failed in bearing, the bolts had commenced to shear at a computed stress of 40,100 lb./in.^{2} These values are probably somewhat in excess of the ultimate strength of rough bolts in shear. For purposes of design this may be taken at 32,000 to 35,000 lb./in.^{2}

Four bolts in specimen 5 sheared at a computed stress of 35,000 lb./in.^{2} The splice plate and welded plates on the lower side of this specimen bowed up. This produced shearing stress in the bolts at right angles to the shear considered in the analysis. The value of the resultant shear may well have been in the neighborhood of those shown by the other specimens that failed in shear. The fact that not all the bolts sheared favors this explanation since the bending of the plates with consequent transverse shear increased toward the middle of the splice plate.

Signs of failure in bearing in the splice plates occurred at average bearing stresses of 109,000 to 125,800 lb./in.^{2} Designs of similar joints on the basis of allowable stresses of 90,000 to 100,000 lb./in. in.^{2} in bearing for structural steel should give splices of adequate strength.

In addition to shear and bearing, the bolts are also subjected to bending. In computing the bending stress in pins in pin-connected structures it is customary to assume that the loads on the pins are concentrated loads acting along the center line of the surface of contact. Since the thickness of the plates is only a small part of the arm of the forces, this method gives results which are sufficiently accurate. If the same method were used to compute the bending stress in the bolts in these specimens,

relatively large errors would be introduced, since the moment arm of the forces would equal the thickness of one plate.

An exact anaylsis of the problem is not possible nor is it necessary. The bolt may be considered as a continuous beam on elastic supports under distributed load. The bending stress under such conditions will evidently be much less than if the same load is considered as concentrated and acting on a simple beam. Moreover, the effect of the nut on the bolt will be to reduce the bending, due to the loads applied to the bolt by the plates. Because of the uncertainty of any assumptions concerning the distribution of the loads on the bolts and on account of the absence of any definite indications of failure due to bending, no attempt has been made to analyze the bending stress in the bolts.

(d) WELDS

Several welded seams of specimen 4 failed at a computed stress of 14,100 lb./lin. in. after the maximum load on the specimen had been reached. The welds of specimens 5 and 6 failed for a short distance at the ends at average computed stresses of 7000 to 11,800 lb./ lin. in., respectively. These weld failures were due to local concentration of stress at the ends of the welds after the specimens had begun to fail elsewhere. The computed weld stresses are, therefore, not indicative of the full strength of the welds. In no case did failure of the specimens begin in the welds. Welds designed according to the provisions of the code for fusion welding in building construction formulated by the American Welding Society should be adequate in strength.

3. *Deflection*

Figs. 8 and 9 show that the load-deflection curves begin to deviate from a straight line at low values of load. This would indicate that portions of the connections were subjected to relatively high stresses at low loads with consequent redistribution of stress in the connections.

For specimens with loads parallel to the web there is a fairly close agreement between the observed values of deflection and the computed deflection of a beam similarly loaded and having a moment of inertia throughout its full length equal to that computed for the weakest section of the splice of the actual beam. The ratio of this moment of inertia to that of the H section varied from 0.13 to 0.30. There is no assurance, however, that this agreement would hold for other lengths of span and methods of loading or for other ratios of moments of inertia. For specimens with loads perpendicular to the web, the actual deflection of the specimens was from 50 to 100 per cent greater than that of beams with a constant moment of inertia equal to that of the splice. The ratio of the moment of inertia at the weakest section of the splice to that of the H section varied from 0.56 for the 14-in. H section of specimen 7 to 1.03 for specimen 6.

4. *Combined Loading*

In an actual structure the column connections are not only subjected to bending stresses, but are also called upon to assist in transferring direct loads from one column to another. The relative magnitude of the

stresses due to direct load and bending will depend among other things on the size and shape of the building and the position of the column in it. In these connections, considered as simple beams, the maximum compressive stresses are small. Considering the column under the action of both types of loading, the compressive stress becomes of major importance and the column may be expected to fail in compression before the ultimate strength of the connection in bending is reached.

The splice will also be subjected to forces which cause bending and shearing of the splice. Transverse shearing of the splice is resisted by the frictional force developed between the ends of the columns and by the shearing stress developed in the splice plates. When the direction of the forces causing shear is perpendicular to the plane of the splice plates, local bending in the plates and tension in the bolts may also be produced. These stresses thus developed should be considered in connection with those caused by bending of the splice.

VII. CONCLUSIONS

The conclusions formed from tests of steel columns consisting of H sections 3 ft. long and 10, 12 and 14 in. wide, connected with splice plates bolted to plates welded between the flanges of the H sections, and tested as simple beams with equal loads at the quarter points of a 66-in. span are:

1. The analysis of stress in these specimens using the simple beam theory gives maximum stress values in the connections which are consistent with the ultimate strength of structural steel.

2. Similar column splices having adequate factors of safety may be designed by these methods on the basis of the values of stresses prescribed by standard building codes for structural steel.

WASHINGTON, Sept. 13, 1929.

Welding of Super Code Pressure Vessels

BY L. H. BURKHART†

THE limitations that the unfired pressure Vessel Code impose on welded vessels has led several companies, of whom ours is one, to work out a welding procedure that is safe and sound and which when applied to the construction of welded vessels of any size and for any pressure, is being recognized and accepted by the insurance companies and by the Code Committees of some states.

Vessels made by these procedures I have termed "Super Code Pressure Vessels" which means that they may be larger than 60 in. diameter for more than 200 lb. pressure and employ a higher unit stress than 8000 lb per sq. in. of weld section.

The procedures that have been worked up by the companies who are doing this welding are more or less secret and are generally described

†Chief engineer, Struthers-Wells-Titusville Corporation, Warren, Pa.

by some trade name such as "Mono-Welding" which describes the process we use. It consists of the use of a specially coated rod of a small gage, multibead manual control welding, with a current value under 200

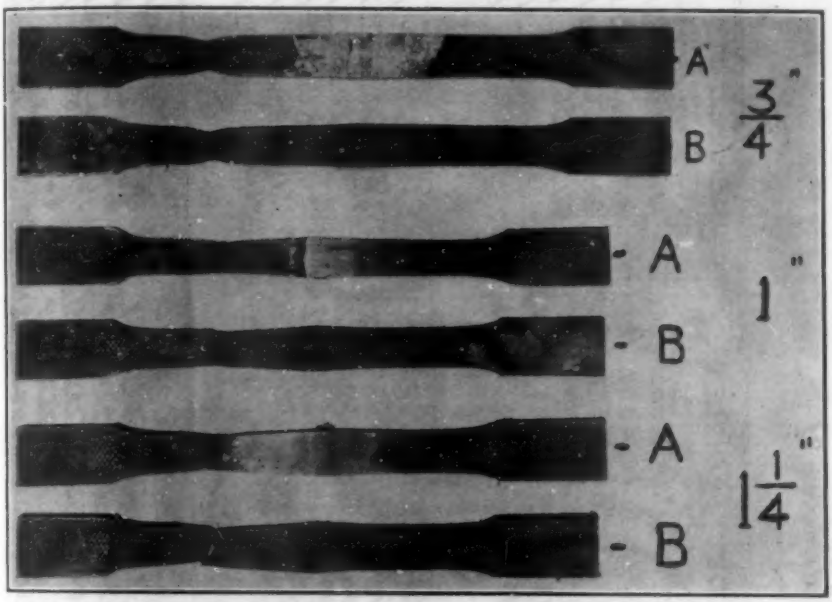


FIG. 1

amperes. On account of the low welding current very little heat is generated, therefore, annealing is not necessary. The joint is the usual double V type. No peaning is used, however, there is no objection to its use. No other special preparation is used.

Understanding as I do the great interest attached to actual tests and results of any welding procedure, I submit the following test reports which are only a few of the many that have been made all with consistent and equal results.

Fig. 1 shows samples ¾ in., 1 in. and 1¼ in. thick. One specimen of each thickness has the welds left as made and one specimen of each thickness has the welds ground off flush with the plate. All specimens broke well out of the weld.

The results of the pull tests are given in Table No. 1.

Since no specimen broke in or near the weld, the test shows the weld to be stronger than the plate. To determine the ductility of such welds specimens were prepared in each thickness of plate viz. ¾ in., 1 in. and 1¼ in. The specimens were cut 2 in. wide, all welds were ground off flush both sides. The ends of the specimens kinked so a free bend could be made with the weld at its center. Circles ½ in. and ¾ in. diameter were scratched on the weld surface and defined with sharp center prick

TABLE I
TENSILE TEST

¾" Specimens

Our Order	Pur. Order	Test Serial	Description	Original Dimension	Original Area	Elastic Limit Pounds	Elastic Limit Lbs. per Sq. In.	Maximum Load Pounds	Tensile Strength Lbs. per Sq. In.	Elongation In. ℄ In.	Elongation Per Cent	After Fracture Dimension	After Fracture Area	Reduction of Area Per Cent.	Fracture
20986-9	¾ A	1	Flush	.700 × 1.508	1.06	32000	30,180	57100	53868	9.81	23	.47×.97	.456	56	In Plate
20986-9	¾ A	2	Flush	.730 × 1.532	1.12	31250	27900	57500	51339	9.25	16	.47×1.0	.470	58	In Plate
20986-9	¾ A	3	Flush	.732 × 1.533	1.10	31750	28863	56800	51636	10.00	25	.47×.97	.456	58	In Plate
20986-9	¾ B	4	Bead	.748 × 1.529	1.14	31900	28000	57000	50000	9.72	21	.47×.97	.456	59	In Plate
20986-9	¾ B	5	Bead	.741 × 1.526	1.14	33000	28947	56000	49122	9.13	14	.47×.97	.456	59	In Plate
20986-9	¾ B	6	Bead	.739 × 1.528	1.13	32800	29026	56000	49550	9.31	16	.47×.97	.456	59	In Plate

1" Specimens

21966-19	1-A	1	Flush	.994 × 1.538	1.53	41100	26900	78600	51400	10-12¼	22.5	.482 × 1.063	.736	52.2	In Plate
21966-19	1-A	2	Flush	.995 × 1.535	1.55	41830	27000	78330	50500	6-6⅝	13.5	.649 × 1.264	.822	52.0	In Plate
21966-19	1-A	3	Flush	.985 × 1.545	1.49	39480	26500	75000	50400	6-7⅛	18.5	.73 × 1.07	.780	48.0	In Plate
21966-19	1-B	4	Bead	.984 × 1.532	1.49	44200	29700	80230	53845	6-7⅛	18.5	.775 × 1.19	.894	40.0	In Plate
21966-19	1-B	5	Bead	.985 × 1.550	1.50	40650	27100	79900	53266	8-10	25	.66 × 1.06	.700	53.4	In Plate
21966-19	1-B	6	Bead	.991 × 1.527	1.51	41850	27715	79100	52384	8-10	25	.69 × 1.03	.740	51.0	In Plate

1¼" Specimens

20164-10	1¼ A	6	Flush	1.241 × 1.535	1.88	50850	27470	104190	55700	10.	25	.94 × 1.13	1.06	.436	In Plate
20164-10	1¼ A	5	Flush	1.249 × 1.535	1.90	51400	27100	104680	55050	9.9	24	1.00 × 1.22	1.22	.360	In Plate
20164-10	1¼ A	4	Flush	1.235 × 1.519	1.89	51500	27200	105600	55950	9.9	24	.87 × 1.19	1.05	.392	In Plate
20164-10	1¼ B	3	Bead	1.226 × 1.50	1.89	50010	27400	104250	55100	9.81	23	1.03 × 1.13	1.13	.404	In Plate
20164-10	1¼ B	2	Bead	1.226 × 1.536	1.93	57600	26220	103650	53750	9.9	24	.90 × 1.25	1.02	.490	In Plate
20164-10	1¼ B	1	Bead	1.226 × 1.509	1.90	49000	25800	103250	54400	9.81	23	.90 × 1.13	1.07	.455	In Plate

marks. Upon bending these circles were elongated into ellipses and represent the elongation of the extreme fibre of the weld.

Bending was done in a hydraulic press and was stopped at the first appearance of a crack.

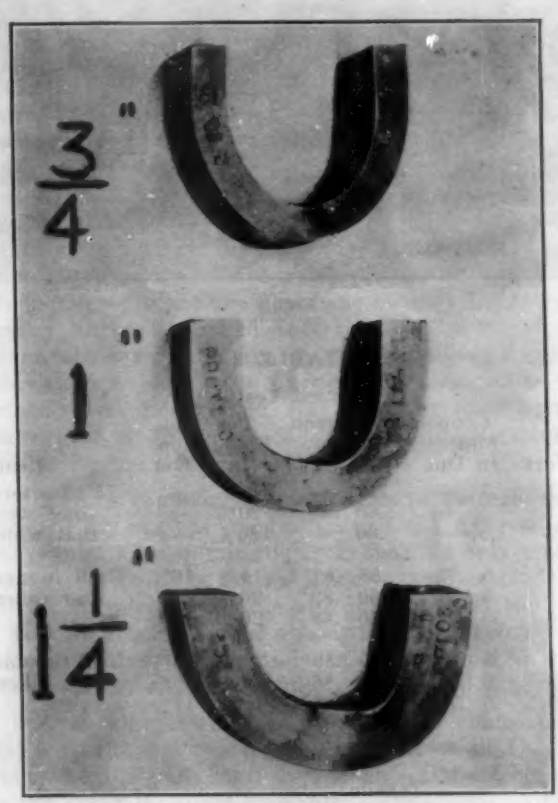


FIG. 2

Fig. 2 shows the bent specimens and table 2 shows the elongation or ductility of the weld metal in the bends.

None of the tests made so far have determined the strength of the weld metal. In order to evaluate this quantity we made up specimens of all weld or deposited metal.

Round bars ½ in. in diameter were machined from these specimens and pulled and table 3 shows the results of the test of the all weld specimens. In this test we find the explanation of why no specimen broke in the weld. The tensile strength of the weld metal is about 50 per cent greater than the tensile strength of the plate used: The elongation about 20 per cent and reduction of area about 30 per cent.

The results obtained as indicated by the foregoing tests fully warrant

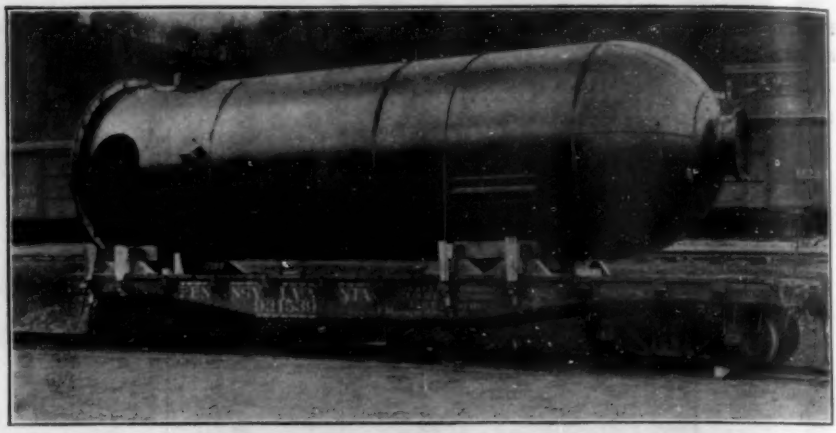


FIG. 3

TABLE 2

Thickness of Plate	Mark	Bend Tests: Coupon Flat In	Coupon Flat Out	Coupon Bent In	Coupon Bent Out	Per Cent Elongation In	Per Cent Elongation Out	Remarks
¾"	1	.5	—	.58	—	16%	—	.75" centers not taken since welds were not that wide.
	2	.5	—	.60	—	20%	—	
	3	.5	—	.60	—	20%	—	
1"	4	.5	.75	.58	.87	16%	16%	Both in and out diameter taken.
	5	.5	.75	.60	.89	20%	19%	
	6	.5	.75	.60	.88	20%	17%	
1¼"	7	.5	.75	.60	.89	20%	18%	Both in and out diameter taken.
	8	.5	.75	.60	.86	20%	15%	
	9	.5	.75	.59	.88	18%	17%	

TABLE 3

Test Serial	Elastic Limit, Lb. per Sq. In.	Tensile Strength, Lb. per Sq. In.	Elongation, Per Cent	Reduction of Area, Per Cent	Fracture
1	54,450	70,550	22.0	33.3	Irregular
2	53,691	71,740	19.0	29.4	Shear

the use of a 100 per cent joint and a unit stress of one-fifth the ultimate strength of the plate used.

Fig. 3 shows a reaction chamber 10 ft. in diameter that has been welded with the Mono-Welding procedure.

Influence of Flux Coated or Covered on the Metal Arc Electrode

M. HARAMIISHI†

IT is a common and wellknown fact that either bare wire or wire coated with flux can be used as an electrode for metallic arc welding, and that each possesses its own merits giving due regard to their respective characteristics.

The theories of metallic arc welding, the transference of molten metal by the arc, the surface effects of bare electrodes and the characteristics of the combined core wire and the flux, have already been studied and discussed by many authorities, and investigations are still progressing. Electrode manufacturers naturally claim several advantages for their own electrodes; and welders, who have got accustomed to the use of a certain electrode and understand its characteristics and method of manipulation, are prone to believe that the one they employ is the best, and to advertise its merits.

Although it may be commonly known to all of you, there is one point which it seems to me has been neglected and not received adequate discussion. The point I have in mind is this: that not only a physical structural change in the metal is taking place in the electrode by the heat of the arc, but a chemical change is also in process at the tip end at the same time. Having observed these phases for many many years, I undertook their investigation and a study of the method of utilizing this chemical action. After adequate study it was found that:

(1) Any desired alloy metal can be obtained chemically in the deposited metal with the flux coated electrode, for while the wire core has some elements which are the main component of the desired alloy metal, the flux has the other requisite elements.

(2) By the utilization of the heat given off by the arc, the characteristic of the deposited metal can be chemically changed from that of the wire core with the prepared flux.

(3) Not only does a chemical change take place ordinarily during the process of transferring the particles of molten metal of the electrode, and also while the deposited metal is molten, but a chemical change occurs in the electrode as well as in the flux immediately the heat of the arc is applied.

(4) Flux, properly prepared, works as a medium in supplying the necessary elements for the desired alloy, and furthermore, also functions in adjusting the heat temperature of the molten metal suitably and protects it against undesirable impurities.

In addition to the foregoing, many important and valuable facts, which

†Tokyo Salvage Company, Ltd., Yodobashi, Tokyo.

are already known, have been traced and checked, and also further light was obtained on the advantages accruing. However, putting those aside here, let me proceed to describe the four items I have tabulated above, in order to permit of a better understanding of the micro-photos which show the facts which were brought to light in the order of my investigations. I should consider it a great privilege if investigators in the United States would be good enough to give me any suggestions and comments on the points I refer to.

Cast Iron

My first attempt was directed to changing the characteristics of the deposited metal to those of grey cast iron, by the use of an electrode whose wire core was of commercial wrought-iron—not any kind of cast-iron bar—and with some flux covered on it. This was hard work, but good results were obtained incidentally in June of the year 1923, after many vexatious trials.

In the Fig. 1, No. 1, is a photo showing the longitudinal section of the electrode core at the tip end used, in which it will be observed distinctly that a small portion at the tip end has been tinted black and the other portion not. No. 2 is a micro-photo showing a cross section of the same at the part not tinted and where the arc heat did not have so much effect chemically. No. 3 is a panoramic micro-photo of No. 1, enlarged 100 times of the original, showing a full length of the small blank portion where the chemical change in the metal core had taken place with the flux, and illustrates the structural phase of white cast iron, and the remaining white portion is similar to micro-photo No. 2 but in longitudinal section. Having stepped up to this stage, those points to be solved and remedied have been duly observed, namely:

(1) The base metal can be well-melted with the electrode, but fusion together at the junction zone is very hard; there was a tendency for the slag to go to the junction zone and be inserted between the base metal and the deposited metal, and consequently they solidified themselves and became hard.
(2) In the microscopic examinations, the deposited metals were mostly seen in the phase with numerous small graphite flakes, and occasionally in the same phase as shown in No. 3, all faintly etched.

Accordingly, labors were next exerted to ascertaining the method of welding manipulation which would give the base metal a good heat conduction and prevent the slag from going to the junction zone; some devices in the flux to keep the deposited metal in the molten condition for a time without injuring or burning it by the arc heat until the graphite would have separated itself, also the most suitable heat temperature for preheating the base metal without using a pyrometer as the latter is not practical in the shop. Also attention was directed to post-heating and slow-cooling of the same.

Having worked out these problems, success was finally obtained and a soft-deposited metal, whose structural phase is that of grey cast iron, was obtained, as shown in micro-photo No. 4, magnified 100 times. No. 5 shows a panoramic micro-photo (X-100 originally) at the junction zone of the base metal at the bottom side and the deposited metal at top side, for which no explanation will be necessary.

It should be added here in order to call attention to the fact, that slow cooling is of vital importance in order to get a soft metal such as cast iron, while rapid cooling is earnestly desirable to obtain a soft metal in cases such as high manganese steel, which will be explained later on.

High Speed Steel

The next effort was exerted to getting a high speed steel, containing tungsten, chromium and vanadium in the deposited metal, using an electrode the core bar of which was of commercial wrought iron, similar to the case of Cast Iron referred to above, and covered with flux in which

FIGURE 2.

Nº 1.

ELECTRODE TIP.
FULL SIZE.

Nº 2.

CROSS SECTION OF CORE BAR.
X100; BY NITRIC-ACID.

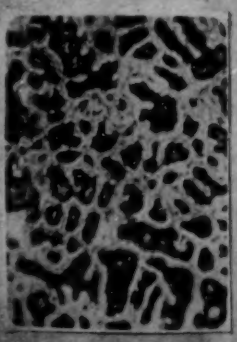
Nº 3.

PORTION OF CORE BAR STILL IN THE ORIGINAL PLATE.

THE LONGITUDINAL SECTION OF THE ELECTRODE TIP END. X300; BY NITRIC-ACID.

TIP END WHERE THE CHEMICAL CHANGE IS TAKING PLACE.

Nº 4.



DEPOSITED METAL
COOLED IN THE AIR.
X500; BY NITRIC-ACID.

DEPOSITED METAL
COOLED RAPIDLY IN AIR.
X500; BY NITRIC-ACID.

tungsten, chromium, vanadium and some other material necessary to make such alloy steel, were mixed together. There was no intention at that time to make any special high speed steel. Preparation of the flux was carried out merely on the basis of obtaining similar results in the deposited metal to those given in "Analyses of High Speed Steel made in 1913 or 1914," described in "The Manufacture and Uses of Alloy Steels" by Henry D. Hibbard.

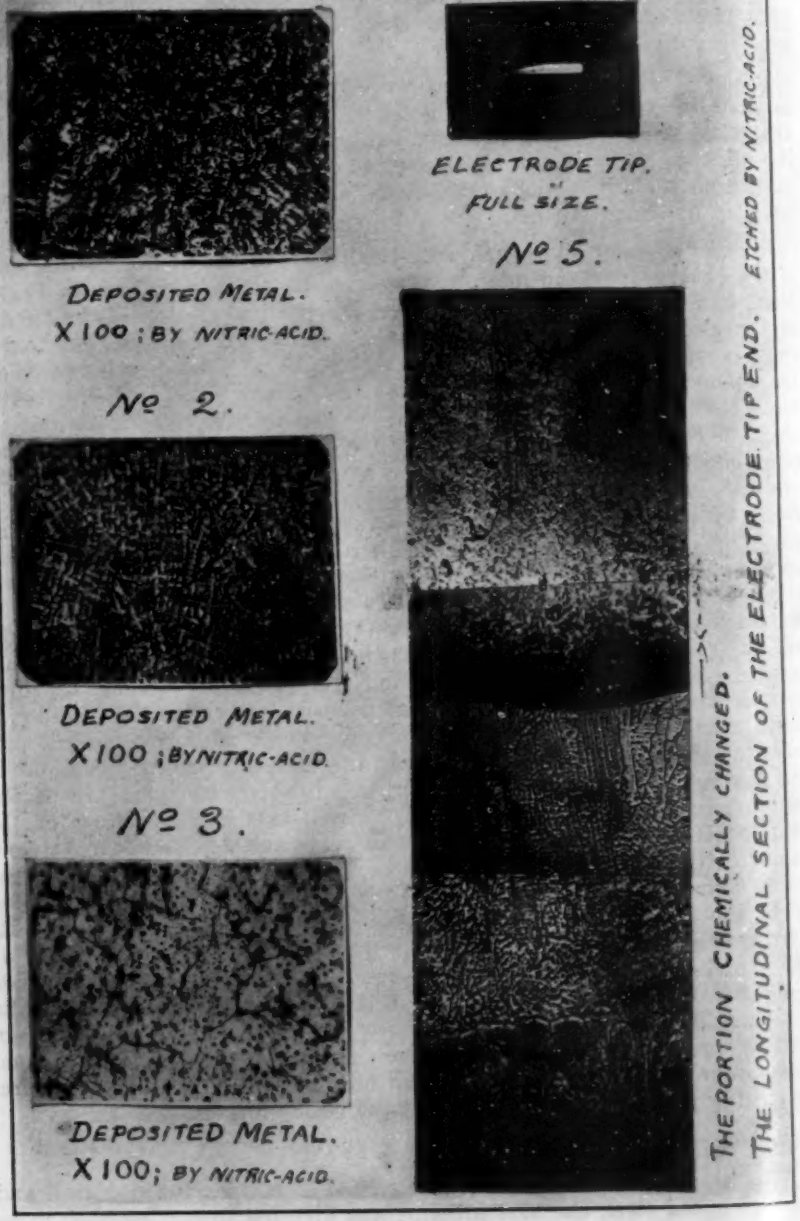
It was very difficult and trying work to arrive at even a hopeful result so that the heat treatments, the hardness tests, the cutting tests, the analyzing, the smith forging tests, etc. had to be carried out many times. Having obtained a result which seemed hopeful, the work was earnestly pushed on till the spring of 1925, and some improvements were carried out also in the meantime.

In order to show you graphically the phases of one of the results, some of the photographs and micro-photos have been produced here in Fig. 2. No. 1 in Fig. 2 is a photograph of the longitudinal section of the tip end of the electrode which was employed, and it may be observed that a small portion at the tip end is tinted black. This black portion is where the chemical change in the core bar had taken place with the coated flux. No. 2 is a micro-photograph X-100 showing the cross section of the electrode core bar used, at the part where the arc heat did not have much effect chemically upon it. No. 3 is a panoramic micro-photo (X-300 the original), showing a full length of the small black portion portrayed in No. 1, by which will be seen the structural phase of the high speed steel naturally cooled by the air, at the bottom side, and the phase of the portion of the wrought iron where there had not then taken place a chemical change, at the top side. No. 4 shows micro-photos X-500 of the deposited metals, in the cast condition—(1) cooled in the air naturally and (2) cooled rapidly in the air. Trained welders can quite easily manage this electrode, as they understand the characteristics of it. However, it seems that the molten metal deposited is rather still hotter in itself and that it has the tendency to swell, which might cause some pinholes in the deposited metal. To avoid this defect, some modifications in the flux might be required in order to adjust the temperature of the molten portion of the electrode end, as well as the temperature of the molten metal in the deposited metal to some suitable degree. At first, in our cutting experiments, it was deposited as the cutting part of the bit on a shank which had been taken from scrap boiler plate, and ground off to the required shape without any reheating. The cutting results were very good. As a next step, the deposited bits were ground off as before and oil quenched to temper at several different degrees Centigrade —400 deg. C. was the most suitable in the trials—and its cutting results were the best. In the last experiment, the deposited bits had been smith forged and ground off to the shape, heat-treated in the usual manner for high speed steel, and then oil quenched to temper as before. Its cutting results were also good but the outlay more expensive.

High Manganese Steel

After the laborious work with the coated electrodes for cast iron and for high speed steel, the next attempt was directed to getting high man-

FIGURE 3.


No 1.
DEPOSITED METAL.
X100; BY NITRIC-ACID.
No 2.
DEPOSITED METAL.
X100; BY NITRIC-ACID.
No 3.
DEPOSITED METAL.
X100; BY NITRIC-ACID.
No 4.
ELECTRODE TIP.
FULL SIZE.
No 5.
THE PORTION CHEMICALLY CHANGED.
THE LONGITUDINAL SECTION OF THE ELECTRODE TIP END. ETCHED BY NITRIC-ACID.

ganese steel in the deposited metal with a coated electrode whose core bar is of commercial wrought iron and coated with a flux which has been prepared with suitable material containing certain quantities of manganese, carbon and other necessary elements.

Having had some experience during the trials of cast iron and high speed steel, suitable fluxes for high manganese steel were prepared without an expenditure of much trouble. There were, however, some points regarding which care had to be exercised in the welding procedure, by reason of the difference in the characteristics of the alloy steels. The micro-photos in Fig. 3 shows these facts thus. No. 1 is a micro-photo X-100 of one of the deposited metals which is very hard, No. 2 a micro-photo X-100 of one of the same but showing the other structural phase which would come out in the high manganese steels when they had been cast in the foundry mould, and No. 3 a similar micro-photo of the phase of the machinable one.

No. 4 in Fig. 3 is a photo of the longitudinal section of the electrode used, and showing the dark colored portion at the tip end where the chemical change had taken place and the molten portion solidified there. No. 5 is a panoramic micro-photo (X-100) showing the No. 4.

By these illustrations, it may be understood that if the electrode had been treated by the usual welding method employed in ordinary low carbon steel welding, the deposited metal might have hardened naturally as shown in the case of No. 1 and No. 2, and the filing would have been practically impossible, because the cooling is still rather slow even then, and heat treatment would be required to make it machinable or sometimes to make it more hard. After several trials, it was found that in order to get the machinable metal the deposited metal should be rapidly cooled by cold air or water, when the molten deposited metal begins to solidify, and otherwise to be slow cooled.

In spite of that, when common steel metals have been deposited and cooled in the air, it is a common fact that their hardness increases and becomes brittle, but with high manganese steel this is not so, as just explained above; and thus it can be assumed as one of the very special cases in arc welding procedure to treat the deposited metal while hot.

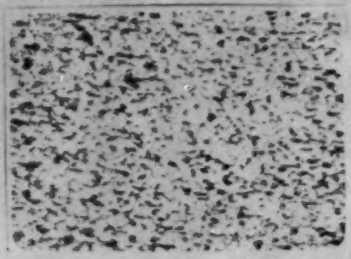
Hypo-Eutectic Steels

Another investigation was carried out on the influence of the flux on hypo-eutectic steels. The object aimed at was to ascertain whether any common steel wire which contains known quantities of carbon, manganese, silicon, etc. could be responsible for changing the carbon and other contents of the deposited metal by the influence of the flux which is coated on.

It is a well known fact that any steel electrode when used loses some quantity of the elements contained in it, and that the characteristics of the deposited metal become quite different from the original. Moreover, it is recognized that steel containing more carbon melts quicker, and therefore, generally speaking, in metallic arc welding, high carbon steel wire as a bare electrode is not suitable for vertical welding or overhead

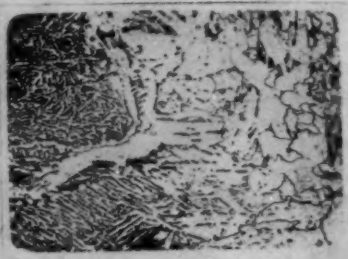
FIGURE 4.

Nº 1.



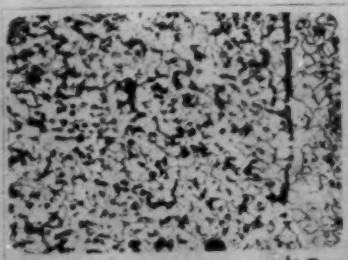
THE ELECTRODE CORE BAR
ANNEALED AT 900° C.C.
X100; BY PICRIC-ACID.

Nº 2.



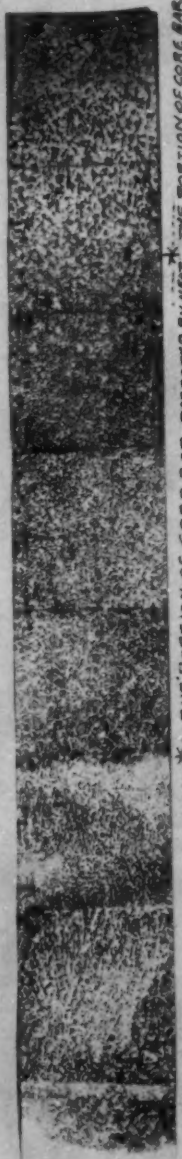
DEPOSITED METEL * BASE METAL.
THE JUNCTION ZONE.
X100; BY PICRIC-ACID.

Nº 3.



DEPOSITED METAL * BASE METAL.
THE JUNCTION ZONE
ANNEALED AT 900° C. C.
X100; BY PICRIC-ACID.

Nº 4.

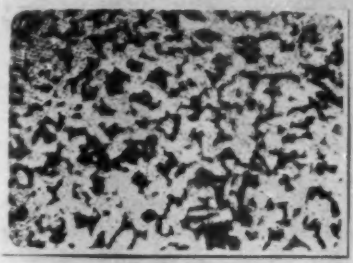


* THE PORTION OF CORE BAR EFFECTED BY HEAT, STILL IN THE ORIGINAL PHASE.
* THE PORTION OF CORE BAR CHEMICALLY CHANGED.
TIPEND

THE LONGITUDINAL SECTION OF THE ELECTRODE TIP END. ETCHED BY PICRIC-ACID.

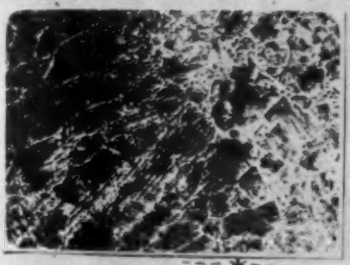
FIGURE 5.

Nº 1:



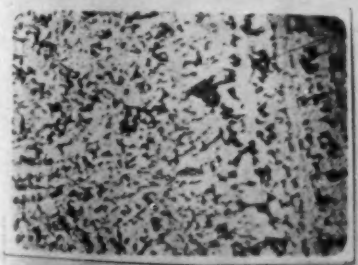
THE ELECTRODE CORE BAR ANNEALED AT 900°.C.
X100; BY PICRIC-ACID.

Nº 2.



DEPOSITED METAL. * BASE METAL.
THE JUNCTION ZONE.
X100; BY PICRIC-ACID.

Nº 3.



DEPOSITED METAL. * BASE METAL.
THE JUNCTION ZONE ANNEALED AT 900°.C.
X100; BY PICRIC-ACID.

Nº 4.

THE TIP END WHERE --- * --- THE PORTION OF CORE BAR WHERE --- * --- THE PORTION OF CORE BAR CHEMICALLY CHANGED. THE HEAT HAS EFFECTED. STILL IN THE ORIGINAL PHASE.

THE LONGITUDINAL SECTION OF THE ELECTRODE TIP END. ETCHED BY PICRIC-ACID.

welding, and it is just possible to manage on flat welding to obtain good fusion with the base metal.

Knowing these facts, several fluxes were prepared and tried in order to learn whether it is possible to keep easily a suitable temperature in the molten metal, and to make up or reject the required elements which have been lost or remained in excess during the welding operation in order to get a desired steel in the deposited metal.

Among the results, micro-photos of three kinds of steel, namely—low, medium and high carbon—are produced here before you. The origin of all these wires was the United States.

Fig. 4 is one set of the micro-photos X-100 of low carbon steel. No. 1 in the set shows a cross section of the original wire annealed at 900 deg. C., No. 2, the junction zone of the deposited metal and the base metal, No 3 the same junction zone shown on No. 2 but annealed at 900 deg. C., and No. 4, the longitudinal section of the electrode tip end displaying where the chemical change had taken place with a properly prepared flux which was coated on the wire.

Fig. 5 is one set of the micro-photos X-100 of medium carbon steel. No. 1 in the sets illustrates the cross section of the original wire annealed at 900 deg. C., No. 2 the junction zone of the deposited metal and the base metal, No. 3 the same junction zone shown on No. 2 but annealed at 900 deg. C., and No. 4 the longitudinal section of the electrode tip end depicting the chemical change which had taken place with a properly prepared flux which was coated on the wire.

Fig. 6 is a set of micro-photos X-100 of high carbon steel. No. 1 in this set is the cross section of the original wire annealed at 900 deg. C., No. 2 the junction zone of the deposited metal and the base metal, No. 3 the same junction zone as shown on No. 2 but annealed at 900 deg. C., and No. 4 the longitudinal section of the electrode tip illustrating where the chemical change had taken place with the suitably prepared flux which was coated on the wire.

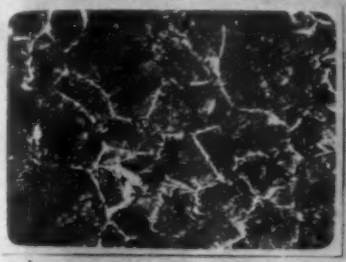
In these micro-photos, it may be observed that No. 1 in Fig. 4, No. 1 in Fig. 5 and No. 1 in Fig. 6 each illustrate the different phases of the steel, while the micro-photos No. 3 in Fig. 4, No. 3 in Fig. 5 and No. 3 in Fig. 6 show practically equal quantities of the pearlite in the phase of each deposited metal. This is due to the effects of the fluxes which had been suitably prepared with different quantities of the elements, according to the different qualities of the steels, to obtain the equal results desired, and also with which the heat temperatures had to be adjusted suitably to weld in any position.

Gun-Metal (Copper, Tin and Nickel)

An attempt was next directed to observe what chemical change with the designed flux would take place at the tip end of the electrode by the heat caused by the arc, and also the effects on the deposited metal after it has been transferred on to the base metal. One of the objects in view was to make a gun-metal sleeve directly on a steel or iron shaft, so that the time and expense involved in the casting machining and

FIGURE 6.

Nº 1.

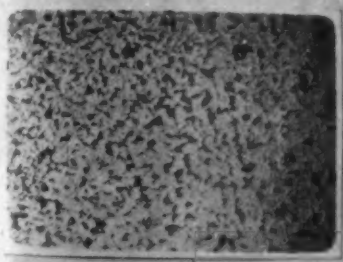


THE ELECTRODE CORE BAR ANNEALE AT 900°.C. X100; BY PICRIC-ACID.

Nº 2.

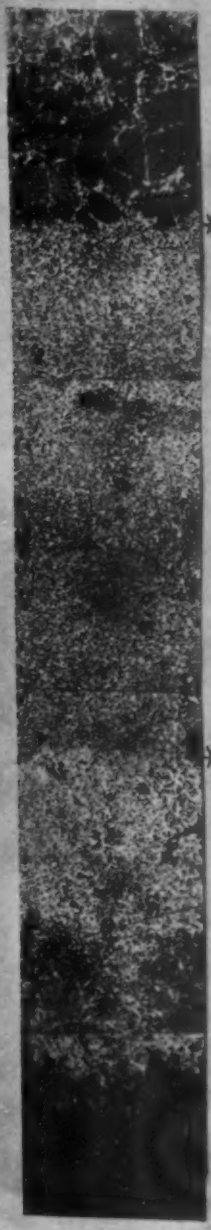
DEPOSITED METAL. BASE METAL.
THE JUNCTION ZONE.
X100; BY PICRIC-ACID.

Nº 3.



DEPOSITED METAL. BASE METAL.
THE JUNCTION ZONE ANNEALED AT 900°.C.
X100; BY PICRIC-ACID.

Nº 4.



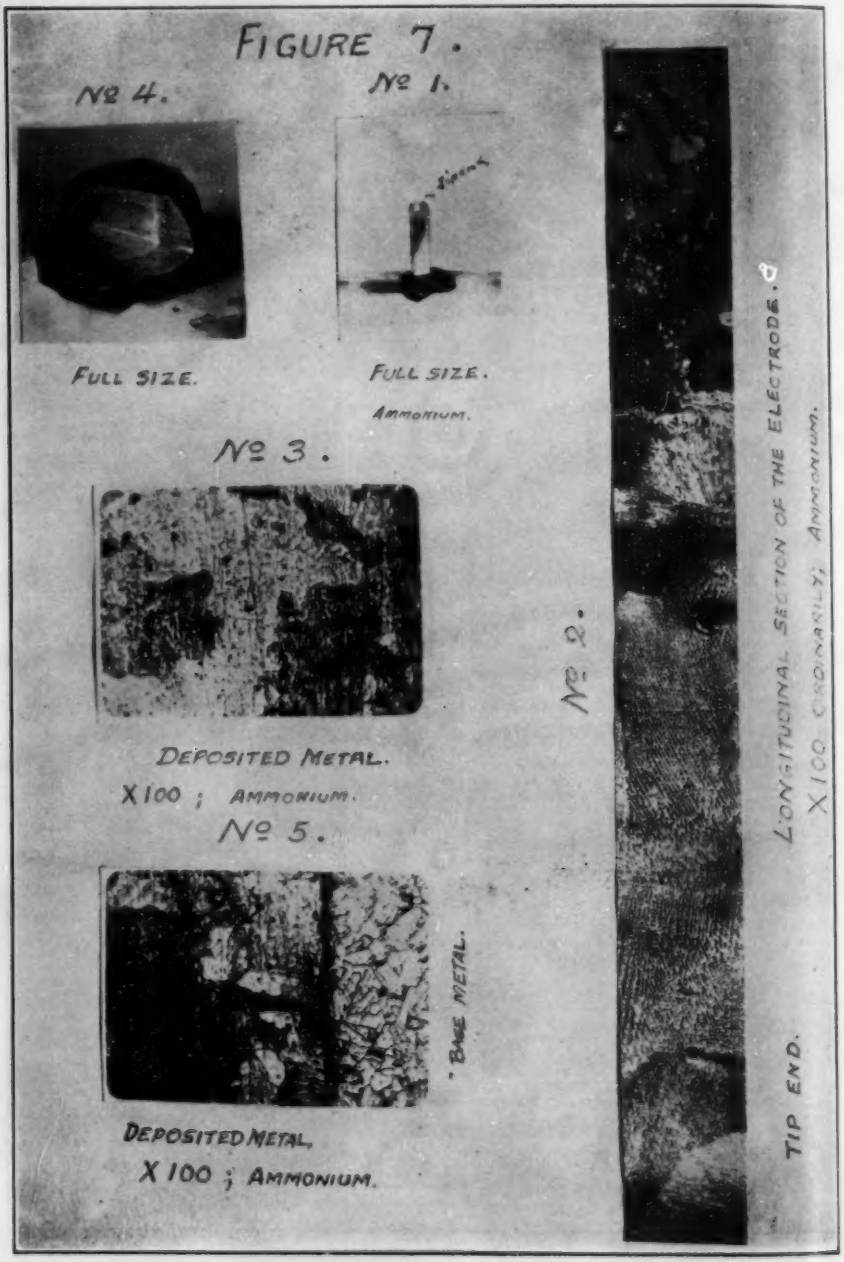
THE TIP END WHERE CHEMICALLY CHANGED.

THE PORTION OF CORE BAR WHERE THE HEAT HAS EFFECTED.

THE PORTION OF CORE BAR STILL IN THE ORIGINAL PHASE

THE LONGITUDINAL SECTION OF THE ELECTRODE TIP END. ETCHED BY PICRIC-ACID.

shrinking-on jobs as at the present time is the common practice, can be altogether dispensed with.



As the coated electrode, copper wire (telegraph wire in quality) was employed for the core bar, and flux containing suitable quantities of tin, nickel and other necessary substances, was coated over it.

More than 200 fluxes were prepared, each with a different proportion of the quantities of the material. The depositing trials were carried out with all of them, to find out the most suitable electric currents and the best welding procedure for the electrodes, and furthermore to ascertain what suitable preparations are necessary for the base metals.

Among these trials, one of the good results obtained is shown here in Fig. 7. No. 1 is a photo of the longitudinal section of the electrode including the tip end, where the small colored portion may be observed. No. 2 is a panoramic micro-photo X-100 the ordinary size showing in part its colored portion where the chemical change with the flux occurred due to the heat caused by the arc, and in part the portion where the heat did not have much effect so as to cause a visible change. No. 3 is a micro-photo X-100 of the deposited metal transferred from the electrode used. No. 4 is a photo of the vertical cut part and the cross section of the steel base metal and the deposited metal. No. 5 is a micro-photo X-100 illustrating the junction zone of the same.

In the welding trials, the following items should be specially noted, viz:

(a) That more electric current is wanted as compared with the case of wrought iron core bar of the same diameter, when the size of the base metal is the same.

(b) That the base metal should be preheated in most cases, because when the electrode itself has been rapidly melted and deposited, the heat is rapidly conducted and absorbed to the base metal, so that a suitable heat should be maintained at the place where the fusion ought to take place, because the temperature there is not sufficient.

(c) That the molten metal should not be too hot as it is liable to swell out while the welding operation (in which care must be taken to let the molten slag float up naturally to the surface of the molten metal) is going on, and blow holes will result.

Even though the physical change due to the arc heat at the electrode tip end and in the deposited metal, when a bare electrode of any sort is used—namely, ferrous or non-ferrous alloyed—may easily be observed, yet it is rather hard to perceive the chemical change at the tip end, because the portion of the electrode where the chemical change is taking place is so very limited, as indicated on the several photographs produced above. Moreover, from the photographs and micro-photos, it will also be understood that the heat in the electrode effected by the arc is occasioning a change of characteristics in the electrode chemically, with the elements in the air, gas or flux—as the case may be—surrounding it before when not only the particles of molten metal of the electrode were being transferred but also deposited onto the base metal.

It is common knowledge that heat temperatures in the electrode and in the deposited metal differ respectively according to the kind of electrode employed, so that with some electrodes it can be easily managed by the welder, but with others it can not. This trouble may often occur especially with bare electrodes because there is no means provided to remedy it except the welder's skill. The flux coated or covered over the

electrode may help the welder considerably in making a good welding job with the proper heat, provided he is very proficient, as the flux can be prepared in such a way as to adjust the heat conduction to a certain extent. This important evidence has been noticed when the electrodes for cast iron have been studied. Since then, during the investigations and the working out of the electrodes for any steels and non-ferrous metals, on which so far I have been engaged, this evidence has always been kept in my mind, and successful results have been arrived at. Bearing this fact before me, I have alluded in the chapter on Cast Iron that "some devices to keep the deposited metal in a molten condition for a time without injuring or burning it by the arc heat until the graphite would have separated itself, is an important and necessary matter." If I could not have secured this important evidence, I feel that my studies on electrodes would have ended in failure.

Copper Welding in the Chemical Industry*

By S. J. Mashl†

BEFORE discussing the possibilities of copper welding, let us first mention a few things about copper, its physical properties, its action under the acetylene flame. By noting the action of the metal under different conditions, we are able to foretell with some measure of accuracy the results that will be obtained when the welding of this metal is actually started.

There are several grades of copper, the purest of which is electrotype copper and is not suitable for welding. The next grade is known as best selected copper, and is used in making bronzes and alloys; the third grade is called tough pitch copper. This is the copper that is most generally used.

Copper has very high heat conductivity and for this reason a larger tip must be used than for steel. It also has a higher coefficient of expansion than steel so we can see that the usual methods of taking care of expansion and contraction must be somewhat different than for steel. Copper is a very soft ductile metal and can be cold worked a good deal, but it has the property of becoming hard and brittle when cold worked. It is very easily annealed by heating to about 700 deg. F. and cooling in air or water as conditions permit.

The tensile strength of cast copper is from 19,000 to 26,000 lb. per sq. in. For pure wrought copper, it is about 36,000, and for wire it ranges from 38,000 to 60,000. Copper loses its strength rapidly with an increase in temperature and at 700 deg. F. the tensile strength is about one-half of what it is at room temperature. The melting point is 2000 deg. F.

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*Paper presented at March 6, 1930, meeting of A.W.S. Chicago Section.

†Van Schaack Bros. Chemical Works, Chicago.

As copper melts, it has a great affinity for oxygen and this forms layers of copper oxide within the metal itself. This is very detrimental, so some means of preventing this oxidation must be used. There are various substances used as deoxidizing agents, the most important being phosphorus, boron-suboxide, aluminum, and silicon.

The rod we use is of great importance. It must contain some substance that will dissolve the oxide and bring it to the surface of the weld or else prevent the formation of the oxide. The rod should have the same melting point as the article to be welded. It should be of uniform composition and the finished weld if properly executed will be strong, tight and ductile.

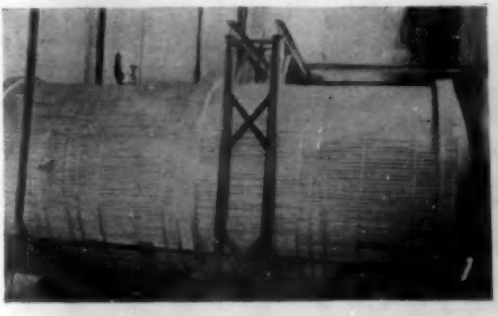

FIG. 1—5,000-GAL. ALL-WELDED STILL MADE OF 8-GAGE COPPER WITH TWO LONGITUDINAL SEAMS WELDED INSIDE AND OUT

FIG. 2—WELDED SEAM IN 490-GAL RECEIVER

When beginning the weld, it is very necessary to have the copper at the melting point before applying the rod. If the rod is added before this temperature has been reached, the rod will only adhere to the surface and we will not have a good weld. This is the trouble with many welders, as the finished weld looks good but lacks strength. Some welders burn the metal by keeping the torch too close to the work and by keeping the same spot molten too long. The best results are obtained when the rod is applied at the same time that the parent metal becomes molten. The two metals then unite to form a perfect weld. In remelting the weld it is very important to always add filler rod to prevent excessive oxidation of the copper.

Annealing the weld after it has cooled has a very beneficial effect on the structure of the weld and increases the strength of the weld.

Welding Procedure in the Plant

In all cases, we try to make plain butt welds, as these are so much easier to make and are as near to being the perfect joint as it is possible to make.

When welding tubing, we always butt the tubes together and tack them

in three or more places and then proceed with the welding. The method used is about the same as for steel with a few exceptions, which are as follows: The part to be welded must first be heated for a few inches to heat up the metal next to the weld, the reason for this being that were this precaution not followed, the first portion of the weld would crack due to too rapid cooling of the adjacent metal. This can be readily understood when we stop and consider the heat conductivity of copper. After heating the parts to be welded, the actual welding is started and is carried on as rapidly as is consistent with good work. The metal is brought up to the point of fusion and at the same time that the metal begins to melt, the rod is inserted into the weld and then carried forward with the weld, with as little puddling as possible. It is easy to obtain a strong weld, but it takes close observation while

FIG. 3—RECEIVING TANK OF 12-GAGE COMMERCIAL COPPER, WITH LONGITUDINAL SEAM BUTT WELDED

welding in this manner if one is to have a weld and not merely add the rod without fusing it properly to the parts being welded. In welding heavy copper sheets it is not possible to weld in this manner. Then one must move the rod as in the welding of steel, always making sure that the part being welded is in a state where it is just about molten and then and not before is the rod to be added to the weld. The metal should never be kept in the molten state without adding filler rod to the puddle. This prevents excessive oxidation of the metal and consequently a poor weld.

In welding long seams we have found it best to start at one end and weld in one direction only. We have tried several methods of controlling the expansion in seams from four to eight feet long and have had good results with the following two: In the first one we had to weld up a seam in eight gage sheet. The seam was 8 ft. 4 in. long. On this we tried bolting two steel angles on either side of the sheet and about 4 in. from the edge to be welded. This was done on both sheets so that it was possible for us to hold the sheets in any position by means of clamps or wedges. The angles prevented the sheet from warping and also acted as chill plates. This method was good but took more time than the following which we now use in preference to any other: To weld a long seam we place the two edges to be welded together on a

straight beam. We use a 4 in. H-beam. Then the edges are hammered down until they lie flat on the beam. We then tack the sheets at one end and put a clamp on the other end to hold the sheets a short distance apart. The welding is then started and as it proceeds the clamp is loosened from time to time to allow the sheets to draw together. Sometimes it is necessary to speed up the rate at which the welding is carried on, in order to prevent the sheets overlapping each other. At other times it is necessary to slow it down in order to prevent the space between the sheets from becoming too wide. When the sheet warps, it is an easy matter to hammer the edges down without interfering too much with the welder. We have approximately eighty seams ranging from 5 ft. long to 10 ft. long in copper sheets that range in thickness from 16 to 8 gage, and up to date we have not experienced any trouble with them. The few leaks that did develop were always small pin holes and no trouble was experienced in repairing them.

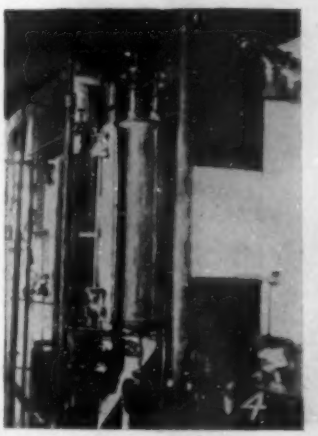

FIG. 4—24 × 8-IN. TANKS OF 16-GAGE COPPER TESTED TO 100 LB. PRESSURE AND USED IN EXPERIMENTAL LABORATORY

FIG. 5—CLOSE-UP VIEW OF OXY-ACETYLENE WELDED SEAM IN 12-GAGE COPPER TANK

In welding tanks, we have found it best to use the butt weld wherever possible, as it is the strongest and easiest to make. The longitudinal seams are first welded and then the heads are welded to the shells. When it is necessary to make the head of two or more pieces, these pieces are first welded together and then the head is flanged over from ¾ to 1½ in. depending upon the size of tank and the gage copper used in it. Flanging the head makes it easy to tack to the shell and this type of construction does away with the welds cracking, as it is very poor practice to make a corner weld in any vessel that is subjected to any pressures or loads such as might be created by the weight of the tank itself or the expansion and contraction of pipe that is connected to the tank.

The illustrations show various articles that have been fabricated in the plant shop. Several of these are of tanks of various sizes and which are used for different purposes. The one shown in Fig. 1 is a still used in the manufacture of ethyl acetate. It is made of 8 gage copper and

the longitudinal seams are welded on both sides. The heads are flanged and sweated to the shell, as is the middle girth seam.

In this still there are two longitudinal seams, the whole body being made of four sheets of copper. It is about 14 ft. long and has a capacity of 5000 gal. The working pressure is very low, not exceeding 5 lb. per sq. in. When the still was completed, it was tested hydrostatically to about 25 lb. per sq. in. There were very few leaks and these were repaired by peening and soldering and to date there are no indications of any leaks.

The tank in Fig. 2 is used as a receiver on a still. It has a capacity of 409 gal. and the seams are copper welded. The heads are flanged and sweated on, the reason for this being that the shell of the tank corrodes much faster than the bottom and we use the same bottom when

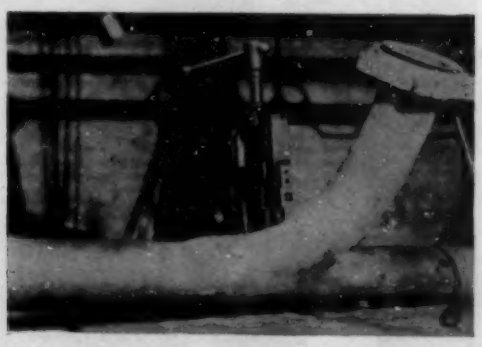

FIG. 6—ACID-METAL FLANGE WELDED TO 3-IN. EXTRA-HEAVY COPPER PIPE (I. P. S.) WITH COPPER ROD

rebuilding the tank by putting on a new shell. There is no pressure on these tanks except the pressure created by the contents. Previous to copper welding these tanks, brazing was used with a hammered lap weld and it always failed in the brazing, the contents of the tank being of such a nature as to eat away the zinc and leave a very porous joint which gave a good deal of trouble. We have practically no trouble with the copper welded seams. They last as long as the shell of the tank itself.

Fig. 6 is a part of a heating coil used in the smaller stills. It has an acid metal flange welded to extra heavy copper pipe with copper rod and the results are very good, as the coils stay tight until the pipe is so thin as to render it unfit for further use.

Before using copper on this joint the flanges were brazed on but had to be rebrazed about every eight or nine months so the saving there is really worth while.

Figs. 6, 7 and 8 show some copper welded fittings that are used in different parts of the plant, the sizes ranging from 1 in. to 5 in. O. D. The working pressures run from zero to 150 lb. steam pressure. The

only leaks are caused by small pin holes once in a while. The welds have never ruptured, which goes to show that they are amply strong for the service imposed on them.

Fig. 9 is one of the standard condensers. This condenser has heads of copper plate ½ in. thick and the tubes are of 16 gage seamless

FIG. 7—HEAT INTERCHANGER WITH END COPPER WELDED

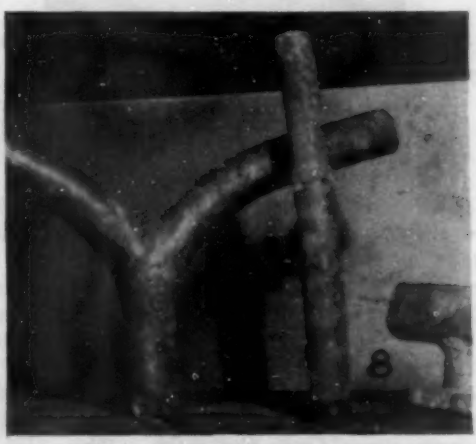

FIG. 8—THIS TEST IS MADE OF 16-GAGE COPPER TUBING, 2 IN. OUTSIDE DIAMETER, WELDED TO COPPER PIPE (I. P. S.)

tubing ½ in. outside diameter and 8 ft. long. There are 199 tubes in the head on ¾ in. centers; these tubes are brazed into the heads.

This presents a problem in brazing, as the difference in thickness of the heads and the tubes is so great that it is almost impossible to heat the head to a red heat without burning the tubes off. The spacing of the tubes also renders it difficult to get the spelter down on the

head without burning the tubes. We solved the problem by using a charcoal preheating fire and allowing sufficient time for the tubes and head to come up to a good heat and we did not get the condenser red hot with the preheating fire. To make the fire hot enough we had to use an air coil with a number of holes in it and forced air through this pipe, which was placed under the fire. This arrangement gave us as much heat as was required and gave good control of the heat also. Forty pounds of charcoal were used in heating the large head and about 30 lb. were used in heating the small head.

The welding procedure was as follows: The head and tubes were assembled and the condenser was placed in an upright position. Then

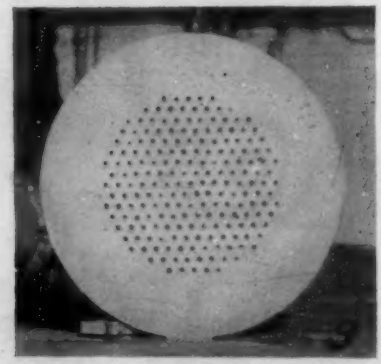

FIG. 9—END VIEW OF CONDENSER MADE UP OF 199 8-FT. ½ IN. OUTSIDE DIAMETER, 16-GAGE COPPER TUBES BRAZED INTO A ½-IN. THICK COLD-ROLLED COPPER HEAD. VESSEL TESTED TO 100-LB. PRESSURE

the preheating fire was started and it required about 1½ hr. to bring the head to the right heat. The next step was to sprinkle some flux over the parts to be brazed. Then we started the actual brazing, using two torhes with a number 12 tip on one and a number 15 tip on the other torch; the former torch was used for the melting of the rod and the other was used for preheating the work. This method enabled us to keep the parts to be brazed at a red heat directly in front of the torch doing the brazing. It was necessary to keep the torches moving at all times so as not to burn the tubes. The torches were also held about an inch away from the work. This also kept the tubes from burning.

In order to keep the brass from running off the work, we undercut the head and this also made it easier to heat. By doing this we had a quarter-inch to fill up with brass which was more than enough for the purpose. When care is used in handling the torches no difficulty is encountered in making a tight job. When finished, the condensers are tested with air at 75 to 80 lb. pressure. There are 14 of these condensers now in actual use and no trouble has developed as yet, although some have been in service nearly two years.

When these condensers were first made, the heads were tinned and the tubes were also tinned into the heads, but the results were very unsatisfactory and the condensers had to be changed about every three weeks, to say nothing of the material that was spoiled and which had to be redistilled. Taking everything into consideration, tinning was an expensive proposition. Up to date, we have not found it necessary to change one of the brazed condensers, which is good proof of the success of the brazed head.

The actual time required to braze one head is about 20 minutes for two welders and one helper. Tinning took one man about three hours, not including the time required to tin the tubes and the head before assembly, but this work was offset by the machining done on the heads when preparing them for brazing. The labor cost for both types of construction is about the same, but the results are vastly different and in favor of the brazed construction. Tin did not have strength enough to hold the tubes when subjected to the expansion and contraction strains set up while the condenser was in operation.

Revisions and Addenda to the Boiler Construction Code*

THE Boiler Code Commission has received and acted upon a number of suggested revisions which have been approved for publication as addenda to the Code. Those related to welding are published below, with the corresponding paragraph numbers to identify their locations in the various sections of the Code, and are submitted for criticism from anyone interested therein. Discussions should be mailed to the secretary of the Boiler Code Committee, 29 West Thirty-ninth Street, New York, N. Y., in order that they may be presented to the committee for consideration.

For the convenience of the reader in studying the revisions, all added matter appears in small capitals and all deleted matter in brackets.

PAR. P-186. REVISED:

P-186. *Welded Joints.* The ultimate strength of a joint which has been properly welded by the forging process shall be taken as 35,000 lb. per sq. in., with steel plates manufactured in accordance with Pars. S-264 to S-279 of Section II of the Code. FUSION [autogenous] welding may be used in boilers, AS HEREINAFTER SPECIFIED PROVIDED THE CARBON CONTENT IN THE STEEL DOES NOT EXCEED 0.30 PER CENT, in cases where the stress or load is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld. Joints between the doorhole flanges of furnace and exterior sheets may be butt or lap-welded by the fusion process, provided these sheets are stayed or otherwise sup-

*Reprinted from May, 1930, issue of *Mechanical Engineering*.

ported around the doorhole opening and provided the distance from the flange to the surrounding row of stays or other supports does not exceed the permissible staybolt pitch as per Par. P-199. If such joints are lap-welded the exterior-sheet flange should preferably be placed on the outside or next to the door opening and the firebox-sheet flange on the interior next to the water. FUSION [autogenous] -welded construction may be used in lieu of riveted joints in the fireboxes of internally fired boilers, provided the welds are between two rows of staybolts, or in the case of flat surfaces the weld is not less than one-half of a staybolt pitch from the corner.

NON-PRESSURE PARTS MAY BE TACK-WELDED TO THE SHELL OR DRUM OF A BOILER, PROVIDED THE STRENGTH OF THE SHELL OR DRUM IS COMPUTED WITH SUCH WELDS CONSIDERED AS THE EQUIVALENT OF HOLES DRILLED THROUGH THE SHELL OF THE FOLLOWING DIAMETERS:

a FOR MATERIAL CONTAINING MORE THAN 0.30 PER CENT CARBON, SUCH AS THAT USED IN FORGED SEAMLESS STEEL DRUMS, THE DIAMETER OF THE EQUIVALENT HOLES SHALL BE TAKEN AS TWICE THE MAXIMUM DIMENSION OF THE WELD, BUT IN NO CASE SHALL A WELD EXCEED 1 IN. IN LENGTH.

b FOR MATERIAL CONTAINING NOT TO EXCEED 0.30 PER CENT CARBON, THE DIAMETER OF THE EQUIVALENT HOLES SHALL BE TAKEN AS THE MAXIMUM DIMENSION OF THE WELD PLUS ½ IN., BUT IN NO CASE SHALL A WELD EXCEED 3 IN. IN LENGTH.

c THE EFFICIENCY OF THE LIGAMENTS BETWEEN ANY TWO OF THE WELDS (CONSIDERED ON THE BASIS OF EQUIVALENT HOLES) SHALL NOT BE LESS THAN THE REQUIRED EFFICIENCY FOR LIGAMENTS OR LONGITUDINAL JOINT OF THE DRUM.

WHERE THE DRUM AND THE ATTACHED PARTS ARE HEAT-TREATED OR STRESS-RELIEVED AFTER THE NON-PRESSURE PARTS HAVE BEEN ATTACHED BY FUSION WELDING, NO DEDUCTION NEED BE MADE ON ACCOUNT OF THE WELD.

THE ENDS OF INNER BUTT STRAPS OF RIVETED BUTT-STRAP LONGITUDINAL JOINTS MAY BE FUSION WELDED TO THE EDGES OF HEADS OR TO THE CIRCUMFERENTIAL BUTT STRAPS FOR TIGHTNESS, PROVIDED THE CARBON CONTENT IN THE STEEL DOES NOT EXCEED 0.30 PER CENT.

PAR. U-23. MODIFY REVISED FORM OF THIS PARAGRAPH AS IT APPEARED IN JANUARY ISSUE TO READ:

U-23. Pressure vessels MAY [shall not] be fabricated by means of fusion welding under the rules given in Pars. U-67 to U-79, PROVIDED THE FABRICATION IS IN ACCORDANCE WITH THE PROCEDURE FOR FUSION WELDING OF PRESSURE VESSELS GIVEN IN THE APPENDIX, AS FOLLOWS [except]:

a Air vessels, when the inside diameter does not exceed 60 [20] in., OR [the length does not exceed 3 times the diameter, and] the working pressure does not exceed 200 [100] lb. per sq. in., OR THE TEMPERATURE DOES NOT EXCEED 250 DEG. FAHR.

b [Other] Vessels [under these rules], in which the circumferential

joints only may be welded, when the inside diameter does not exceed 48 in., or 72 in., when at least 75 per cent of the load on a flat head is supported by tubes or through stays extending from head to head.

c VESSELS OF ALL KINDS AND OF ANY DIMENSIONS, IN WHICH ALL JOINTS MAY BE WELDED, PROVIDED THAT IN ADDITION THE RULES GIVEN UNDER THE "SPECIFICATIONS FOR FUSION WELDING OF DRUMS OR SHELLS OF POWER BOILERS" ARE FOLLOWED (these Specifications were published in the February, 1930, issue of JOURNAL OF THE AMERICAN WELDING SOCIETY. [Where the vessels are fabricated in accordance with the recommended procedure for fusion welding of pressure vessels given in the appendix, the limiting diameter in par. U-23*a* may be taken as 60 in. and the limiting pressure may be taken at 200 lb. per sq. in., provided the temperature does not exceed 250 deg. fahr.]

PAR. U-59*f*. Change the letter of this section to "*g*" and insert new section "*f*" to read as follows:

Nozzle Fittings, Fusion Welded. *f* NOZZLES MAY BE FUSION WELDED, WITH OR WITHOUT REINFORCEMENT, TO THE SHELL OR TO THE SPHERICAL PORTIONS OF THE HEADS AS PERMITTED IN PAR. U-77, PROVIDED THE FABRICATION IS IN ACCORDANCE WITH THE PROCEDURE FOR FUSION WELDING OF PRESSURE VESSELS GIVEN IN THE APPENDIX. SUCH FITTINGS SHALL BE HEATED FOR STRESS RELIEF IN ACCORDANCE WITH THE REQUIREMENT OF PAR. U-72 AND AS SPECIFIED IN FIG. U-3.

PAR. U-65. MODIFY REVISION SHOWN IN THE OCTOBER, 1929, ISSUE OF "MECHANICAL ENGINEERING" TO READ:

U-65. Every pressure vessel shall be inspected at least TWICE [once] by a state or municipal inspector of boilers, or an inspector employed regularly by an insurance company which is authorized to do a boiler-insurance business in the state in which the vessel is built, or in the state in which it is to be used, if known [which inspections shall be made one before reaming rivet holes or finally closing the vessel to inspection, and the other when the hydrostatic pressure test is on] IN THE CASE OF A RIVETED VESSEL, ONE INSPECTION SHALL BE MADE AT THE TIME OF REAMING RIVET HOLES. IN THE CASE OF A VESSEL FABRICATED IN WHOLE OR IN PART BY A WELDING PROCESS, ONE INTERNAL INSPECTION SHALL BE MADE BEFORE FINAL CLOSURE. A FINAL INSPECTION SHALL BE MADE AT THE TIME OF THE HYDROSTATIC TEST. A data sheet shall be filled out and signed by the manufacturer and the inspector, which data sheet, together with the stamping on the vessel, will denote that it is constructed in accordance with these Rules. [Every pressure vessel fabricated in whole or in part by a welding process, shall, when the size of the shell permits, be internally inspected before being finally closed to inspection.]

PAR. U-67. REVISED:

U-67. *Processes.* The fusion process, so-called, shall consist of welding by means of either the oxyacetylene process or ANY [the] electric-arc process, using welding wire, either bare, coated, or covered, OR MELTING DOWN THE BASE METAL.

PAR. U-68. MODIFY REVISED FORM OF THIS PARAGRAPH SHOWN IN JANUARY ISSUE TO READ AS FOLLOWS:

U-68. When welded in accordance with the Procedure for Fusion Welding of Pressure Vessels given in the Appendix, the strengths of joints may be calculated on a maximum unit working stress (*S*), at right angles to the direction of the joint, as follows:

[For] Butt double-V [longitudinal] welds FOR ALL JOINTS.....8000 lb.
[For] Butt single-V FOR girth or head welds.....6500 lb.
[For] Double full-fillet lap [or girth] welds, FOR GIRTH JOINTS ONLY .....7000 lb.
[For spot or intermittent girth or head welds.....5600 lb.]

[Unless the Procedure for Fusion Welding of Pressure Vessels given in the Appendix is followed in all particulars, the unit working stress (*S*) at right angles to the direction of the weld shall not exceed 5600 lb. per sq. in. (see Par. U-20).]

PAR. U-70. REVISE FIRST SENTENCE TO READ AS FOLLOWS:

The base metal of shells shall not exceed 5/8 in. thickness, EXCEPT AS PROVIDED IN PAR. U-23c.

PAR. U-71. REVISED:

U-71. Method of Welding. Longitudinal seams shall be of the double-V type, that is, welded from each side [halfway through the sheet]. Girth and head seams may be of the single-V type, that is, welded entirely through from the outside. Double-V welds shall be reinforced at the MIDDLE [center] of the weld on each side [of the plate] by at least 1/16 IN. UP TO AND INCLUDING 5/8 IN. PLATE [25 per cent of the plate thickness]. Single-V welds shall extend entirely through the plate and shall be reinforced at the MIDDLE [center] of the weld by AT LEAST 1/8 IN. UP TO AND INCLUDING 5/8 IN. PLATE [not over 20 per cent of plate thickness]. All welds shall be of sound metal, thoroughly fused to the sides of the V for its entire depth. Sheets must not be allowed to lap during welding. In material 1/4 in. THICK OR LESS THE SINGLE-V TYPE OF JOINT MAY BE USED FOR LONGITUDINAL SEAMS, AND THE BEVELING OF THE EDGES FOR EITHER LONGITUDINAL OR CIRCUMFERENTIAL SEAMS MAY BE OMITTED IF A BACKING-UP STRIP IS USED TO INSURE COMPLETE PENETRATION OR IF THE JOINT IS WELDED FROM BOTH SIDES [or less in thickness, the longitudinal seams need not be beveled. In material less than 1/4 in. thick, beveling the heads will be sufficient, and the shell need not be beveled at the head seams. One side of each girth seam shall be beveled].

There shall be no valley either at the edge or in the MIDDLE [center] of the joint, and the weld shall be so built up that the welded metal will present a gradual increase in thickness from the surface of the sheet to the MIDDLE [center] of the weld.

At no point shall the sheet on one side of the joint be offset with the sheet on the other side of the joint in excess of one-quarter of the minimum thickness of the sheets, or plates.

PAR. U-72. RENUMBER THIS PARAGRAPH AS U-73, AND INSERT NEW PAR. U-72 TO READ AS FOLLOWS:

U-72. THE PART OR PARTS OF THE VESSEL SPECIFIED FOR STRESS RELIEVING SHALL BE HEATED UNIFORMLY AND THE TEMPERATURE INCREASED

SLOWLY TO AT LEAST 1100 DEG. FAHR. AND HELD AT THAT TEMPERATURE FOR A TIME AT LEAST PROPORTIONAL TO ONE HOUR PER INCH OF THICKNESS, AND SHALL THEN BE ALLOWED TO COOL SLOWLY IN A STILL AIR. IF THE VESSEL IS NOT SUFFICIENTLY RIGID TO RETAIN ITS SHAPE AT THE ABOVE TEMPERATURE, THE HEATING SHALL TAKE PLACE AT 1000 DEG. FAHR. FOR A TIME AT LEAST PROPORTIONAL TO THREE HOURS PER INCH OF THICKNESS.

ANY ONE OF THE FOLLOWING METHODS OF DETERMINING THE EXTENT OF HEATING IN STRESS RELIEVING WILL BE CONSIDERED SATISFACTORY:

a HEATING THE COMPLETE VESSEL AS A UNIT.

b HEATING A COMPLETE SECTION OF THE VESSEL (HEAD OR COURSE)

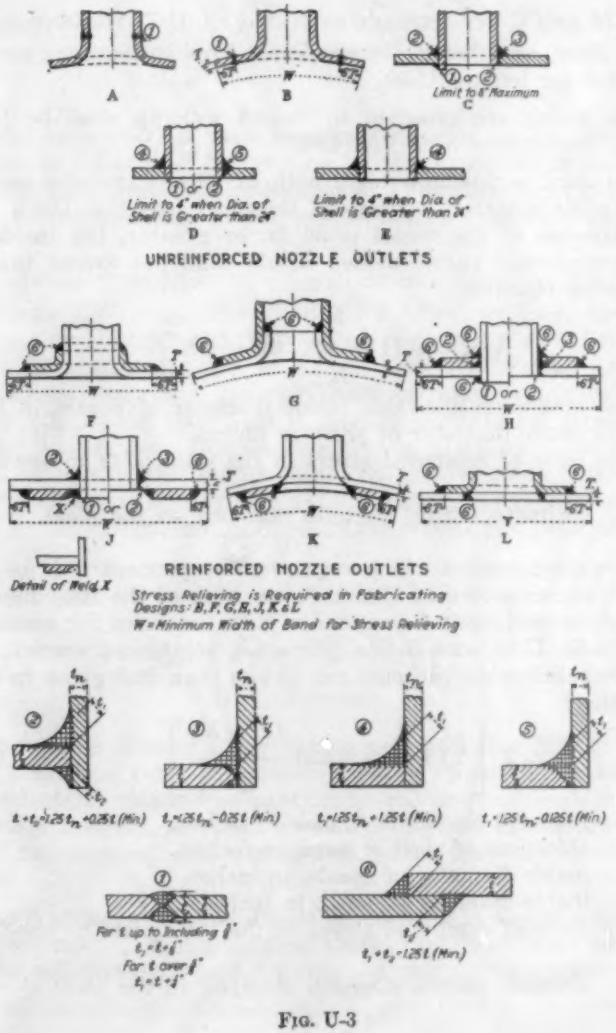
A
B
C
Limit to 8" Maximum
Limit to 4" when Dia. of Shell is Greater than 24"
D
Limit to 4" when Dia. of Shell is Greater than 24"
E
UNREINFORCED NOZZLE OUTLETS
F
G
H
J
K
L
Detail of Weld X
REINFORCED NOZZLE OUTLETS
Stress Relieving is Required in Fabricating Designs: B, F, G, H, J, K & L
W = Minimum Width of Band for Stress Relieving
t = t_n + 1.25 t_n + 0.25 t (Min)
t_1 = 1.25 t_n + 0.25 t (Min)
t_1 = 1.25 t_n + 1.25 t (Min)
t_1 = 1.25 t_n + 0.125 t (Min)
For t up to Including 1"
t_1 = t + 1"
For t over 1"
t_1 = t + 1"
t_1 = t_2 + 1.25 t (Min)

FIG. U-3

CONTAINING THE PART OR PARTS TO BE STRESS RELIEVED BEFORE ATTACHING THE SECTION TO OTHER SECTIONS OF THE VESSEL.

c HEATING A CIRCUMFERENTIAL BAND HAVING A MINIMUM WIDTH OF *W* AS SHOWN IN FIG. U-3, IN SUCH A MANNER THAT THE ENTIRE BAND SHALL BE BROUGHT UP TO THE UNIFORM TEMPERATURE REQUIRED FOR STRESS RELIEVING.

PAR. U-73. RENUMBER THIS PARAGRAPH AS U-74 AND REVISE TO READ:

U-73. *Distortion.* The cylinder or barrel of a vessel shall be [substantially] circular at any section WITHIN A LIMIT OF 1 PER CENT, and if necessary to meet this requirement shall be reheated, rerolled or reformed.

PARS. U-76 AND U-77. REPLACE BY NEW PAR. U-77 TO READ AS FOLLOWS:

U-77. *Inlet and Outlet Connections.* Pipe connections may be made as provided for in Par. U-59.

Nozzles which are attached by fusion welding shall be formed and welded in accordance with Fig. U-3.

Nozzles may be fusion-welded, with or without reinforcement, to the shell or to the spherical portions of the head (see Fig. U-3). When the inside diameter of the vessel is 36 in. or greater, the inside diameter of an unreinforced fusion-welded nozzle shall not exceed that given in the following equation:

$$d = 0.1155 \frac{D}{K} \sqrt{6K - 5K^2 - 1}$$

where d = maximum allowable inside diameter of nozzle, in inches.
D = inside diameter of shell, in inches.
K = ratio of computed stress in the solid plate to one-fifth of the ultimate tensile strength stamped on the plate, $= \frac{PR}{St}$.

Fusion-welded nozzles which require reinforcement may be of the reinforced type, as shown in Fig. U-3. Nozzles of the type shown in Fig. U-3*K* shall be designed in accordance with the rules for manholes given in Pars. U-55, U-56, and U-57. For other reinforced nozzles, the thickness of the reinforcing pad may not be less than that given in the following equation:

$$t = T \left[3.75 \frac{d}{D} - 0.525 \frac{(1 - K)}{K} \right]$$

where t = required thickness of pad, in inches.
T = thickness of shell or head, in inches.
d = inside diameter of nozzle, in inches.
D = inside diameter of shell, in inches.
K = ratio of computed stress in the solid plate to one-fifth of the ultimate tensile strength stamped on the plate $= \frac{PR}{St}$.

The thickness of the reinforcing pad shall not be less than ¾ in. when the thickness of shell or head to which the same is fitted is 2 in. or less; when thickness of head or shell is greater than 2 in., the minimum thickness of the pad shall be 1 in. The width of the pad along the longitudinal axis of the shell, or any axis of a head, shall not be less than the inside radius of the nozzle, less the nozzle thickness.

Nozzles which are attached by fusion welding in vessels whose seams

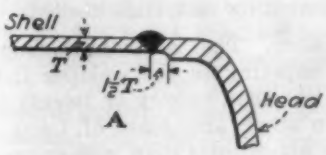

FIG. U-3½A

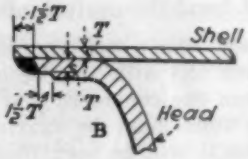

FIG. U-3½B

are of riveted construction shall be attached prior to the making up or attachment of the courses by riveting, or if they do not require stress relieving, shall have such nozzles located at a distance from the riveted seam equal to the diameter of the nozzle plus 4 times the shell plate thickness.

PAR. U-87. REVISE SIDE HEADING AND FIRST SENTENCE TO READ:

U-87. *Stress Relieving.* [Annealing.] After welding, the entire [whole] vessel or cylinder shall be heated UNIFORMLY AND [to a] THE temperature INCREASED SLOWLY AT LEAST 1100 DEG. FAHR., AND HELD AT THAT TEMPERATURE FOR A TIME AT LEAST PROPORTIONAL TO ONE HOUR PER INCH OF THICKNESS [sufficient to remove the internal strains], and SHALL [then] BE allowed to cool slowly in A STILL AIR [the air]. IF THE VESSEL IS NOT SUFFICIENTLY RIGID TO RETAIN ITS SHAPE AT THE ABOVE TEMPERATURE, THE HEATING SHALL TAKE PLACE AT 1000 DEG. FAHR. FOR A TIME AT LEAST PROPORTIONAL TO THREE HOURS PER INCH OF THICKNESS.

Job Shop Welding

H. L. FETTER†

THE job welding shop of today has an ever-widening field of activity. A few years ago some automobile welding, repair and maintenance work for industrial plants was practically the limit of such shops. In this connection I might say that we still find plant executives who are unaware of the savings both in time and money that can be effected by welding.

Therefore it appears that intelligent advertising is an important factor in the management of a job welding shop. Our experience has proved that personal solicitation is best for this purpose. Photographs of actual

†Manager, Rochester-Welding Works, Rochester, N. Y.

work done are a help in convincing the doubtful. Telephone directory advertising and occasional newspaper items are also good.

In the early days of the welding industry steel and cast iron were practically the only metals thought weldable. Today the up-to-date welding shops that really understand their job are welding alloy steels, stainless steels, acid-resisting iron, aluminum, monel metal, stellite and copper and bronze mixtures of every nature successfully. To do this it is necessary to employ skilled welders who know the proper procedure and have at hand the equipment and welding materials needed.

This necessitates a well-organized shop. The "blacksmith shop" type of welding shop has little chance of competing in the welding industry of today. When one considers that no less than twenty or twenty-five types of welding rods must be carried in stock and most of these types in various sizes it will be seen that no hit-or-miss plan will answer. Storage bins along the walls of the shop will be found most satisfactory. In this way each type and size of rod may be kept separate.

The modern shop should have a special preheating floor so that large castings, punch presses, gear wheels, etc., can be handled. For today there is no limit to the size of castings that can be successfully welded and adequate floor space is essential.

In addition to a well equipped shop portable outfits for both electric and oxy-acetylene welding in the field are needed. Boiler welding, welding of pipe lines, and repairs to shovels and dredges furnish large possibilities to the welding shop.

It might be of interest to briefly mention a few successful jobs of recent years that a short time ago would have been impossible.

It has always been possible to weld cracked bells but after welding it was generally found they would not ring true. However, in one instance, a small section of a church bell was taken, analyzed, welding rods made up to same specifications, the bell welded and the tone found to be unimpaired.

In 1928 we welded twenty-five tons of $\frac{5}{8}$-in. copper plate successfully. The plate and also the welding rods for this job were made to specifications furnished by our shop.

Recently, by the use of silver solder, an acid resisting tank was successfully welded.

The above-mentioned jobs and many more show the need of a technical knowledge of the principles of welding if a progressive shop is to be operated.

The electrical contractor is finding a use for the job welding shop in building up worn armature shafts and also for welding extensions onto the shaft. This work can be done without damage to the armature. The welding is readily machined and when turned to proper size it looks like a new shaft.

Special tanks, truck bodies, etc., can be welded to advantage.

More automobile and truck welding is being done today than ever before. This is another reason for larger and better equipped shops for

there must be room to drive cars and trucks in and out of the shop. Jobs in this line most encountered in welding shops include broken truck frames to be welded and reinforced, crank cases, cylinder blocks, housings, fenders, bumpers and tail-gates.

The farmer should be educated to what the welding shop can do for him. In this connection folders, blotters, calendars, etc., can carry him the message of welding as a time saver for breakdowns during cultivating and harvesting seasons.

Hard facing metals are being used successfully. Additional life of from three to five times is added to many types of metal where a hard wearing surface or other part resistant to abrasion is needed. Equipment for drilling, cement mill machinery, equipment used in quarries and mines, dredge buckets, special machine forming tools, scrapers, cams, plow shares and trip levers have been successfully treated in this way.

The welding of large aluminum casting has been reduced to a science. Preheating is necessary in most cases to prevent distortion. If the proper procedure is followed and a good rod used success is assured.

The housewife, too, has need of the welding shop. Vacuum cleaner parts, washing machine parts, stove and furnace grates, oven doors, hot water coils, lawn mower parts and innumerable other articles may be welded at great savings.

Cutting by means of the oxy-acetylene torch is in wide use. It is the most effective means of cutting up steel castings of unusual size and is therefore used in large sized scrapping operations and also in machinery and plant layout changes.

Perhaps the most noteworthy advance in the practices of job welding shops has been the progressing from strictly maintenance and repair work into production work of various types. Here, again, proper advertising is of great importance. By giving publicity to past successful jobs the shop will secure new business of a similar nature.

The larger shops are also branching out into various types of construction work. This is a comparatively new field for the welding shop but it has vast possibilities and will undoubtedly come to be more widely used as time and experience prove it to be the most effective method of joining steel structures.

Ornamental iron work, because of its increased use, can be advantageously introduced into welding shops. Door handles, latches, hinges and knockers of wrought iron for the summer home may be easily made. Lanterns and sconces for electric lights, window grilles, balconies, railings, gates and inclosures of all kinds may also be useful on the summer estate. There is a large field for welded iron work inside as well as outside the summer home. And irons, fire screens tongs, shovels and pokers are just a few suggestions of the possibilities.

Finally a job welding shop to succeed and make money must eliminate guesswork in figuring costs. Labor, materials used, depreciation and overhead must all be taken into consideration. The welder must keep a record of the time required to complete each job and the materials used. Only in this way can the cost be accurately determined.

Training Course for Aircraft Welders*

R. W. Boggs† and S. C. Clark††

WITHIN the last few years the world has become air-minded to a degree far exceeding the expectations of even the most enthusiastic proponents of aviation of a decade ago. Each year the production of airplanes for commercial and private use has exceeded the estimates made at the beginning of the year.

It is well known that the American aircraft industry has standardized on welded steel tubing construction for fuselages, landing gear and other parts, the most recent development being the extension of this method of fabrication to wing construction. This fact, coupled with the constantly growing production of aircraft, has resulted in an ever-increasing demand for trained oxy-acetylene welders capable of producing the high quality of work that is essential in this field.

Experience in other industries having shown that application of procedure-control principles insures welded construction of highest quality, it was natural that procedure control should be adopted by the aircraft industry where quality is a prime requisite. It will be remembered that qualification of welders is one of the six points emphasized in procedure control. Training welders in accordance with these principles will consequently produce welders most capable of meeting the demands of the aircraft industry.

This article outlines a training course for aircraft welders based on the firmly established principles of procedure control. Obviously the instructor in charge of such a course should be thoroughly familiar with all phases of procedure control as well as with actual factory operations and other technical features of aircraft production.

Lesson 1

Lecture—1. Oxy-acetylene process for welding and cutting metals. Fundamental principles, development, industrial importance. Oxygen and acetylene. 2. Functions of apparatus. Brief description of blowpipes and regulators by means of cross-section drawings. 3. Precautions and safe practices. Opening valves, adjusting regulators, blowing out hose, why hose is of different colors.

Demonstration—1. Set up of equipment, adjusting regulators, lighting, adjusting and extinguishing flame. 2. Effects of neutral, carbonizing (excess acetylene), and oxidizing flames on steel plate. 3. Proper method of making ripple weld on flat plate without rod.

Shop Work—The student should practise setting up equipment, adjusting regulators, lighting, adjusting, and extinguishing blowpipe flame as

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†Mechanical Engineer, Union Carbide Co.
††Resident Engineer, Linde Air Products Co.

in the demonstration. Using pieces of 22 to 16 gage sheet steel, study effects of neutral, excess acetylene, and oxidizing flames on steel. On pieces of sheet steel slightly inclined as in Fig. 1 make forward ripple welds without rod.

LESSON 2

Lecture—Blowpipes (low pressure and pressure types). Principles, construction, care of tips, valves and hose.

Demonstration—1. Proper cleaning tips. 2. Making and inspecting hose connections. 3. Splicing hose.

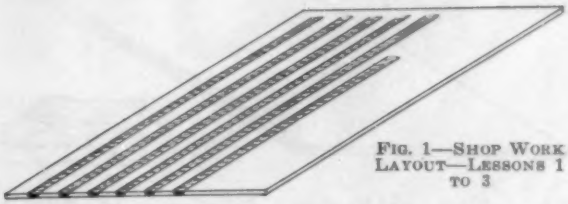

FIG. 1—SHOP WORK LAYOUT—LESSONS 1 TO 3

Shop Work—Continue practice in making forward ripple welds without rod as in Lesson 1 and Fig. 1.

LESSON 3

Lecture—1. Regulators, different types and their construction. Care of regulators and minor repairs. 2. Function of welding rod. Carrying a puddle, using rod. Forward and backward welding.

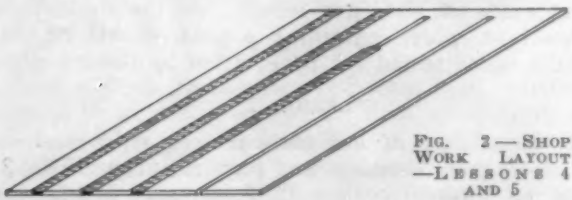

FIG. 2—SHOP WORK LAYOUT—LESSONS 4 AND 5

Demonstration—1. Assembly of regulators. 2. Making forward ripple welds on steel plate with rod. Making forward and backward fillet welds with rod.

Shop Work—After further practice in making forward ripple welds without rod the student should practise making the same type of weld using welding rod.

LESSON 4

Lecture—1. Oxygen. Production, cylinders, precautions in handling. 2. Acetylene. Methods of generating, safe pressure. Reason for combining with acetone in cylinders, precautions in handling. 3. Generators, types.

Demonstration—Charging of generator—if one is available.

Shop Work—Using pieces of 22 to 16 gage sheet steel slotted as shown in Fig. 2 make forward ripple butt welds with rod. Test occasional welds for penetration by bending in vise.

LESSON 5

Lecture—Cutting. Difference between cutting and welding blowpipes. Spontaneous burning of red hot iron or steel in oxygen. Reason for the heating flames. Starting and maintaining a cut.

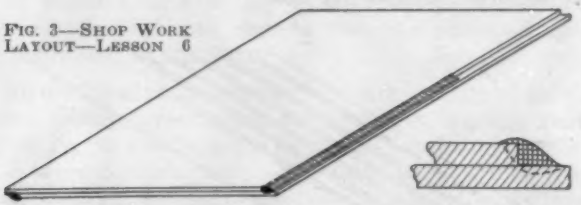

FIG. 3—SHOP WORK LAYOUT—LESSON 6

Demonstration—Burn welding rod in oxygen to show principle of cutting. Cutting with blowpipe.

Shop Work—Cutting steel plate. Continue making forward ripple butt welds as in Lesson 4, testing occasional welds by bending.

LESSON 6

Lecture—Review of past week's lectures, with stress on Lecture 1.

Shop Work—Lap two pieces of 22 to 16 gage sheet steel as shown in Fig. 3. Make forward and backward fillet welds along both lapped edges using rod, cut welds off plate and repeat. As the student acquires proficiency, strips 1 in. wide, containing a weld, should be cut into 1-in. squares and the welds tested for penetration by forcing plates apart.

LESSON 7

Lecture—1. Metallurgy of low carbon steel, mild steel and chrome-molybdenum steel, their chemical and physical properties. 2. Tests for recognition of the different grades. 3. Importance of high quality welding rod of proper grade.

Demonstration—Show how to distinguish between different grades of steel discussed in lecture, by welding, melting, etc.

Shop Work—Repeat shop work in Lesson 6. Set up and tack two pieces of 22 to 16 gage sheet steel as shown in Fig. 4 with one plate vertical. The position of the other plate should vary from horizontal to vertical in the series of specimens welded by the student. Make forward corner welds without rod and with rod. Test occasional welds for penetration by bending.

LESSON 8

Lecture—Significance of carbon content of steel. Effect of other than neutral flames on the puddle and finished weld. Overheating of puddle and adjacent base metal. Effect of heat on chrome-molybdenum

steel. Desirability of using a moderate flame and making as small a weld as consistent with maximum strength, to prevent overheating of chrome-molybdenum base metal.

Demonstration—Welding the different grades of steel, showing results of improper flame adjustment and overheating.

Shop Work—Make forward butt and fillet welds with rod as in Lessons 4 to 6 except that the sheet being welded should be supported so as to

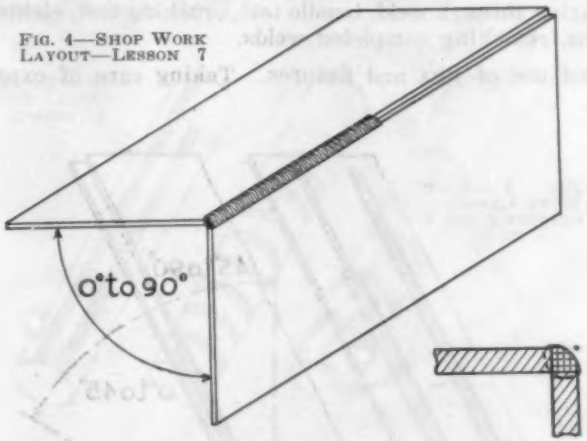

FIG. 4—SHOP WORK LAYOUT—LESSON 7

form an angle with the surface of the welding table varying from 0 to 45 deg., for the series of specimens welded during this shop work period. This is indicated in Fig. 5.

LESSON 9

Lecture—Good welding technique and character of satisfactory welds. Cleaning edges to be welded of scale, etc. Spacing of joints and tacking, when required. Fusion, size and contour of weld, penetration to root of fillet and to inner side of butt weld. Importance of smooth fillet at junction of weld and base metal. Remelting tack welds and remelting when tying into a previously made weld.

Demonstration—Welding tee and lattice joints of tubing, illustrating points in lecture.

Shop Work—Continue the shop work of Lesson 8 with the sheets set at angles varying from 45 to 90 deg. as indicated in Fig. 5. Occasional welds should be tested as was done in previous lessons.

LESSON 10

Lecture—Theoretical discussion of fuselage joints, tensile and compressive members. Why center lines should intersect at a common point. Why gusset plates, insert plates and fish mouth joints are used.

Demonstration—Show typical joints on board and discuss character of stresses.

Shop Work—Set up and tack a 1-in. strip of sheet steel at right angles to the surface of a larger piece of the same material as shown in Fig. 6. Make forward and backward fillet welds along both sides of the strip. Repeat, varying the angle at which the strip is set on the plate and also the angle which the base plate makes with the surface of the welding table as shown in Fig. 6.

LESSON 11

Lecture—Various methods of testing welds, by bending from both sides, fracturing through weld, tensile test, crushing test, etching polished cross-sections, remelting completed welds.

Design and use of jigs and fixtures. Taking care of expansion and contraction.

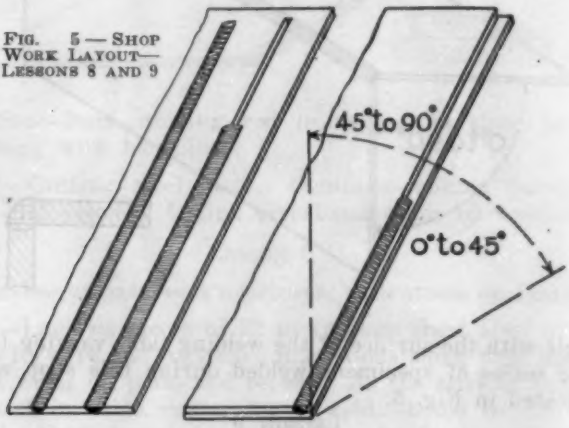

FIG. 5 — SHOP WORK LAYOUT— LESSONS 8 AND 9

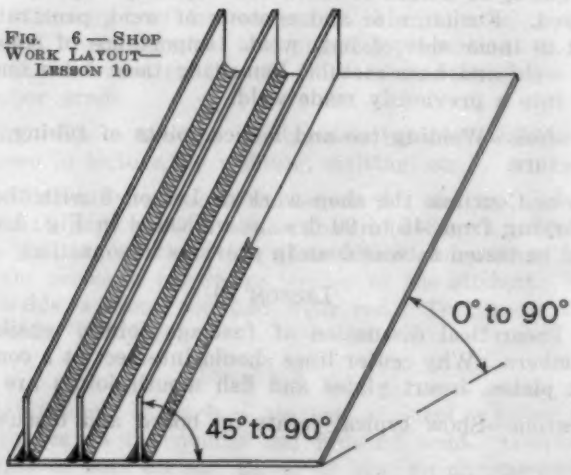

FIG. 6 — SHOP WORK LAYOUT— LESSON 10

Demonstration—Test welds by all above methods for which facilities are available. Show how tubes and joints may be distorted by heat and methods of controlling distortion.

Shop Work—For this and subsequent lessons requiring the use of tubing, the following materials should be used: mild steel tubing, Army and Navy Specification 57-180-1A or S.A.E. 1025; chrome-molybdenum tubing, Army and Navy Specification 57-180-2A or S.A.E. 4130X. Tubing sizes should vary from ¾ to 2 in., the corresponding wall thickness varying from 0.028 in. to 0.065 in.

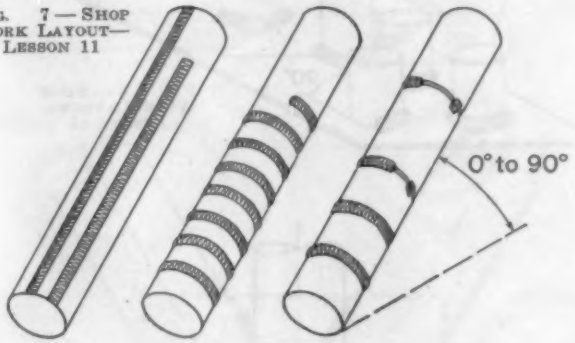

FIG. 7 — SHOP WORK LAYOUT— LESSON 11

As shown in Fig. 7, make longitudinal welds using rod on the surface of tubing inclined from horizontal to vertical position. Make rotating and position welds using rod on surface of tubing inclined from horizontal to vertical. These welds may be made in a continuous spiral, if desired. Make open butt welds of the rotating and position types on pieces of tubing lined up and tacked as shown at the right in Fig. 7.

Test open butt welds occasionally for fusion, penetration, and size by etching cross-section.

LESSON 12

Lecture—Review of past week's lectures with stress on 8 and 9.

Shop Work—Set pieces of tubing perpendicular to a piece of 22 to 16 gage sheet steel as shown in Fig. 8. Make forward and backward fillet welds joining tubing to plate. Test occasional welds by remelting weld metal to determine soundness, fusion and penetration.

LESSON 13

Lecture—Line up of fuselage, landing gears, tail surfaces, motor mounts, etc.

Demonstration—Demonstrate according to lecture.

Shop Work—Continue Lesson 12 with the tubing set at angles varying from perpendicular to 45 deg. as shown at the right in Fig. 8. Make forward and backward fillet welds. Test occasional welds by remelting.

LESSON 14

Lecture—Bronze-welding. Welding aluminum, stainless steels, etc.

Demonstration—Show use of flux in welding as discussed in lecture.

Shop Work—Repeat the shop work in Lessons 12 and 13 with the plate in vertical position.

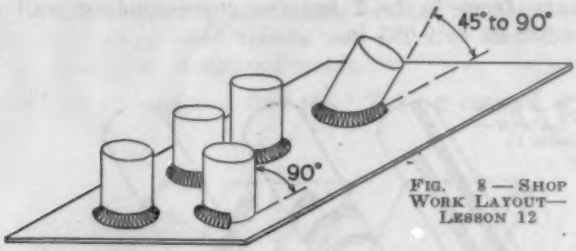

FIG. 8—SHOP WORK LAYOUT—LESSON 12

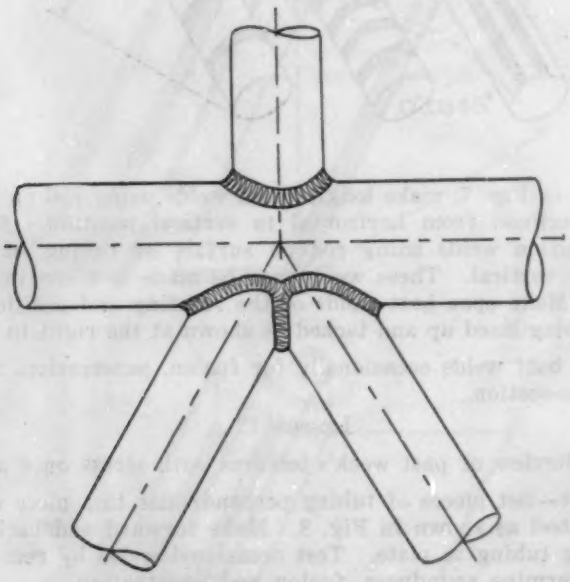

FIG. 9—SHOP WORK LAYOUT—LESSON 15

LESSON 15

Lecture—Airplanes in general. Factory production methods. Simple aerodynamics.

Shop Work—Continue welding tubing to plate making position welds. Preparation, set up, tacking and welding of tee and lattice joints with tubing. Fig. 9 is a typical joint. Make forward and backward welds

with main section of tubing horizontal on table. Test occasional welds by remelting weld metal and by etching cross-sections to determine soundness, fusion and penetration.

Lessons 16 to 20

Lectures—Repeat Lectures 1 to 5.

Shop Work—Continue work outlined in Lessons 14 and 15.

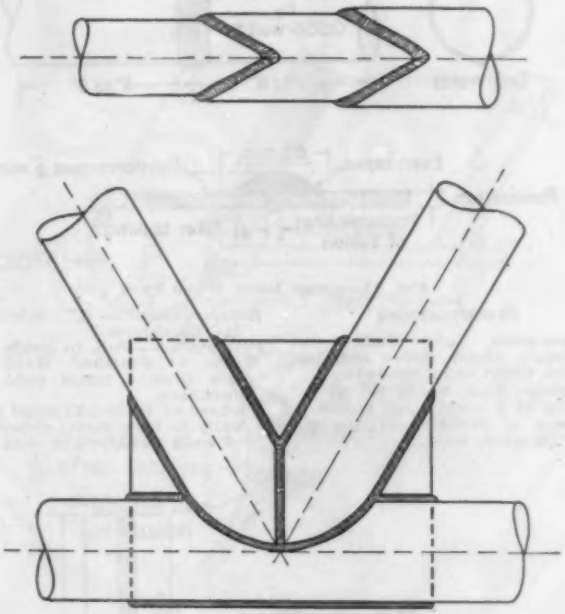

Fig. 10—Shop Work Layout—Lessons 23 to 27

Lesson 21

Lecture—Repeat Lecture 6.

Shop Work—Make overhead welds without rod on steel sheet. With sheets prepared as in Fig. 2, make overhead welds with rod. With sheet prepared in the same way, make forward and backward welds with rod with the plate vertical and the slots horizontal. Test occasional welds for penetration by bending in vise.

Lesson 22

Lecture—Repeat Lecture 7.

Shop Work—With tubing prepared as in Fig. 7 and as in Fig. 9 make overhead welds with axes of all tubes horizontal. Test occasional welds by remelting weld metal and by etching cross-section to determine soundness, fusion and penetration.

Lessons 23 to 27

Lectures—Repeat Lectures 8 to 12.

Shop Work—Prepare joints as shown in Fig. 10 and as more complicated joints in a fuselage are constructed. Make welds in the position in which joints would be located in regular production work. Test

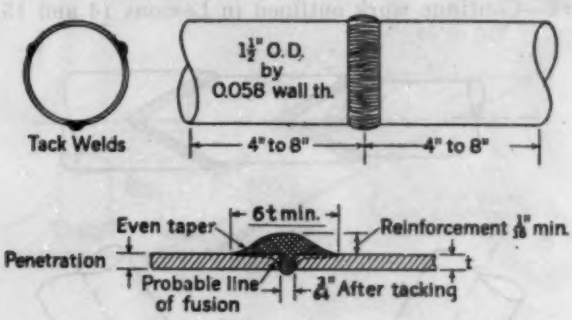

Fig. 11—Open Butt Weld Test

Specifications

Preparation of Ends—Cut square, clean inside and out past width to be welded.
Tacking—Tack welds 1/16" to 1/4" long at 3 equidistant points.
Method of Welding—Tubes rotated while welding.
Reinforcement—1/16" minimum, 1/8" maximum.
Penetration—Full, to inside wall.
Width of Finished Weld—Not less than 6 times tube wall thickness.
Contour of Weld—Tapered gradually to base metal either side of weld as shown in detail.

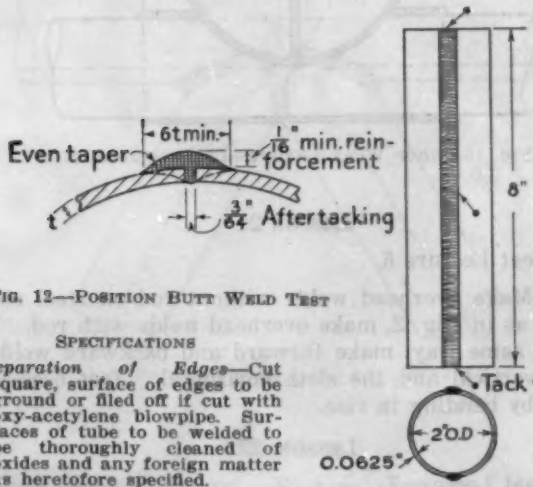

Fig. 12—Position Butt Weld Test

Specifications

Preparation of Edges—Cut square, surface of edges to be ground or filed off if cut with oxy-acetylene blowpipe. Surfaces of tube to be welded to be thoroughly cleaned of oxides and any foreign matter as heretofore specified.
Tacking—Tack welds 1/16" to 1/4" long where marked.
Method of Welding—Tube secured in a vertical position. Weld vertical, starting at bottom of specimen.
Reinforcement—1/16" minimum, 1/8" maximum.
Penetration—Full, to inside wall.
Width of Finished Wall—Not less than 6 times tube wall thickness.
Contour of Weld—Tapered gradually to base metal either side of weld, as shown in detail.

occasional welds by remelting weld metal particularly where they were started and closed out. Also etch cross-section to determine soundness, fusion and penetration.

LESSON 28

Lecture—Repeat Lecture 13.

Shop Work—Preparation and welding test specimens to pass qualification test. Specifications for preparation, welding and testing of specimens shown in Figs. 11 to 17.

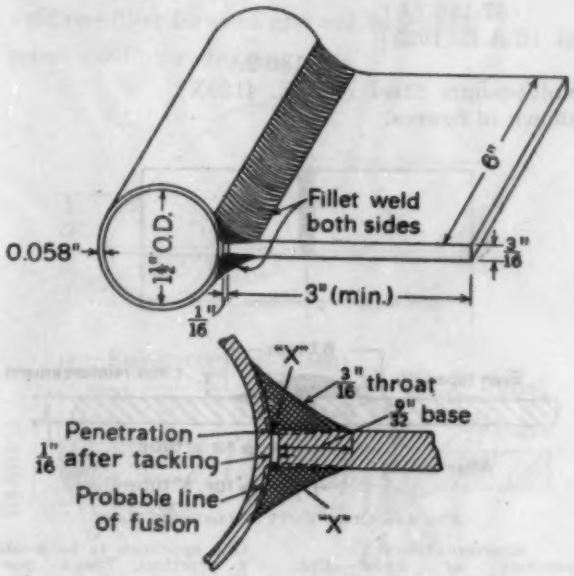

FIG. 13—FILLET WELD TEST

SPECIFICATIONS

Preparation—Edge of plate abutting tube to have square cut. Surface of edge to be ground or filed off if cut with oxy-acetylene blowpipe. Surfaces of tube and plate to be welded to be thoroughly cleaned of oxides and any foreign matter as heretofore specified.

Tacking—Tack welds 1/8" to 1/4" long, both sides, near ends of plate.

Method of Welding—Tube clamped to table so welds can be made in a horizontal position.

Dimensions of Weld—As shown in detail. Fillet contour to taper gradually at either side of weld.

Penetration—To the root of the fillet or to point "X."

LESSON 29

Lecture—Repeat Lecture 14.

Shop Work—Special coaching and retesting in cases of failure in Lesson 28. Otherwise, welding on regular fuselage.

LESSON 30

Lecture—Repeat Lecture 15.

Shop Work—Welding on regular fuselage.

Qualification Tests for Aircraft Welders

The following tests should be passed by a welder before he is allowed to weld upon aircraft structures. Preliminary tests may be omitted at the option of the inspector (welding foreman or instructor), if the welder or student has previously been under observation. Failure to satisfactorily pass the preliminary tests should eliminate the welder from further consideration and save the time and expense of the final tests.

Material

(57-180-2A)
Mild Steel (S.A.E. 1025)

(57-180-2A)
Chrome-Molybdenum Steel (S.A.E. 4130X)
Sizes as shown in figures.

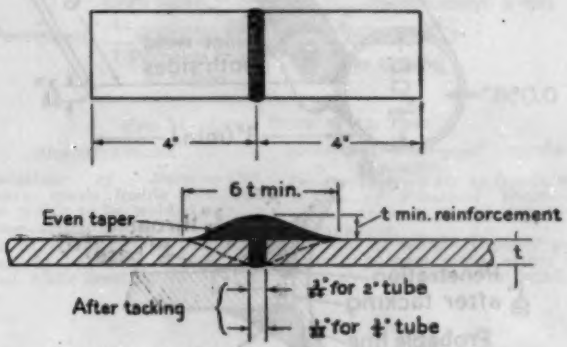

Fig. 14—Open Butt Collapsing Test

Specifications

Preparation of Ends — Cut square. Surfaces of tubes to be welded including surfaces inside joint, to be thoroughly cleaned of oxides and any foreign matter as heretofore specified.

Tacking—Tack welds 1/4" to 1/4" long at three or more equidistant points.

Method of Welding—Two specimens to be rotated during welding, tube to be horizontal. One specimen to be welded in a vertical, fixed position. Welding to be done forward or backward. Backward is recommended.

Reinforcement—Wall thickness minimum, 1/4" maximum.

Penetration—Full, to inside wall.

Width of Finished Weld — Not less than 6 times tube wall thickness.

Contour of Weld—Tapered gradually to base metal either side of weld.

Preliminary Tests

1. *Rotative Butt Welds*—Welder to make an open butt weld joining two short sections of tubing for each of the two grades of steel specified herein. The designs and specifications for this test specimen are given in Fig. 11.

2. *Position Butt Welds*—Welder to make an open butt vertical weld joining two sections of 2-in. tubing in either of the two grades of steel specified herein. The designs and specifications for this test are given in Fig. 12.

3. *Horizontal Fillet Welds*—Welder to make a fillet welded specimen,

joining a 3/16-in. plate to a 1½-in. tube section in either one of the two grades of steel specified herein. The design and specifications for this test specimen are given in Fig. 13.

The material should be thoroughly cleaned before welding in the regions of welding, of all oxides or any foreign matter. Cleaning can be done either with a stiff wire brush, a file or emery paper or by grinding if necessary.

Welder to select tip and determine gas pressures.

Welder to weld one fillet forward and one backward.

Welder to select welding rod size.

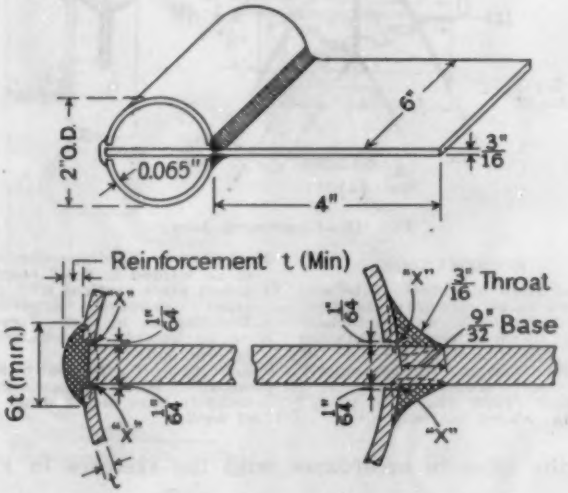

FIG. 15—INSERT PLATE JOINT TEST

SPECIFICATIONS

Preparation of Edges — Cut square. Surfaces to be welded including surface inside joints to be thoroughly cleaned of oxides and any foreign matter as heretofore specified.

Tacking—Four tack welds, two each side, near end of plate at point of fillet welds and two tack welds near ends of plate at point of butt weld.

Method of Welding—Specimen to be placed in convenient position for each of the three welds. Welding is to be done forward or backward. Backward is recommended.

Reinforcement — As shown for fillets. For the butt weld, wall thickness minimum, 1/8" maximum.

Width of Finished Welds — As shown.

Contour of Weld—Tapered gradually to base metal either side of weld.

The welding inspector should, during the welding operations, look for the following factors of manual skill (a to l, inclusive) of the welder and shall determine whether he has sufficient skill to proceed with the final qualification tests.

(a) A clean welding tip.

(b) Soft neutral welding flame, neither pointed nor irregular.

(c) Penetration to inside wall of tube, or to points "X" and to see if welder permits excessive weld metal to protrude into the tube.

(d) "Floating out" of oxides or any dirt in the weld puddle.

(e) Even fusion into the base metal.

(f) Regular movement of the blowpipe.

(g) Occasional check for neutral flame, by throttling back to neutral indication, a momentary excess of acetylene.

(h) Uniform incorporation of filler material with the progressing weld puddle.

(i) Production of a regular weld contour and proper tapering of the

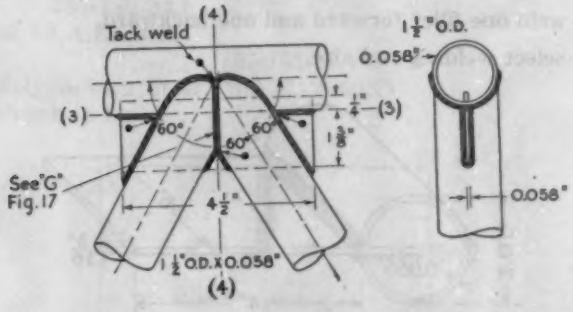

FIG. 16—COMPOSITE JOINT

SPECIFICATIONS

Preparation of Joints—Intersections to be carefully matched. Surfaces to be welded including surfaces inside joints, to be thoroughly cleaned of oxides and any foreign matter as heretofore specified.

Tacking—Tack welds ⅛" to ¼" long where marked.

Method of Welding—Specimen to be welded in fixed position, insert plate vertical with principal member uppermost. Welding to be done forward or backward. Backward is recommended.

Penetration—To the root of fillet.

Contour of Weld—Tapered gradually to base metal either side of weld.

weld along the sides in accordance with the sketches in Figs. 11, 12 or 13.

(j) Maintenance of clean, molten metal at all times during the welding operation.

(k) Proper incorporation of the tack welds into the final weld, particularly the fusion at such points.

(l) Proper "closing out" of weld at finish where the progressing weld engages the start of the weld, where care should be exercised on the part of the welder to see that the finish of the weld is thoroughly penetrated into the previously made weld.

The fillet welds in specimen Fig. 13 are to be remelted by aid of a suitable welding flame, to expose the character of the weld such as its fusion, penetration and the general density of the deposited metal.

FINAL QUALIFICATION TEST

If the welder has satisfactorily passed the preliminary tests set out above, he should next be required to pass the following final qualification tests.

4. *Open Butt Collapsing Test* (Rotative and Vertical Position Welding)—This test requires the welding of three specimens similar to Fig.

14 in either of the two grades of steel specified. Two of the three specimens should be rotated during the welding operations for the convenience of welder, the specimens being at all times horizontal with respect to the longitudinal axis. The welding should be done in accordance with the specifications accompanying Fig. 14.

To test the three specimens, crush between the jaws of a vise or parallel faced heads of a press until reduced to one-half the original diameter. Any test weld in aircraft tubing that is cracked by this treatment should be considered unsatisfactory.

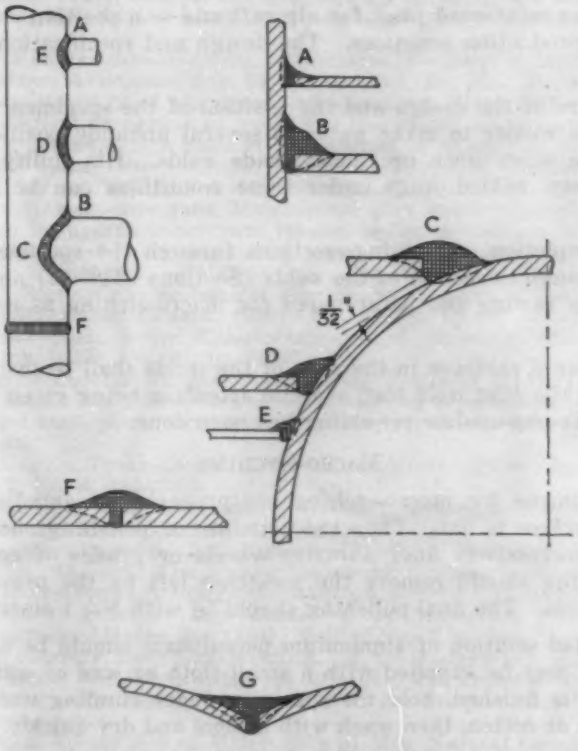

FIG. 17—DETAILS OF TEST WELDS

5. *Insert Plate Joint. Fillet Weld Test* (Horizontal Welding)—This test requires the welding of one specimen similar to Fig. 15, in either of the grades of steel specified herein. The specifications accompanying Fig. 15 inform the welder of the welding requirements governing this test specimen. Upon completion of welding, the specimen shall be cut in sections at points 1½ in. from the front and back edges of the specimen, Fig. 15. The surfaces of these sections (one for each section exposed) should be prepared for macro-etching as recommended below.

The prepared surfaces in the zone of the welds shall be inspected for the following factors:

(a) Conformity of dimensions of welds to those given in Fig. 15.

(b) *Penetration of Welds*—Fillet welds shall have full penetration to the points marked "X." The tee butt weld shall have full penetration to the points marked "X."

(c) *Fusion*—The several welds shall be uniformly and completely fused to the base metal at all points of contact.

(d) Sound weld metal, free from gas pockets or holes, fissures, plates of oxides, laps or similar defects.

6. *Composite Joint* (General Position Welding)—This test is specified for the purpose of observing the welder's ability to weld a typical four-member reinforced joint for aircraft and in a position characteristic to that of production practices. The design and specifications are given in Fig. 16.

The nature of the design and the position of the specimen for welding requires the welder to make welds in several unhandy positions, also to superimpose welds upon previously made welds. His ability to produce a satisfactory welded joint under these conditions can be thus determined.

Upon completion of welding, sections through the specimens shall be exposed through the center of the welds (Sections (3)—(3) and (4)—(4) Fig. 16), by sawing and be prepared for macro-etching as recommended below.

The prepared surfaces in the zone of the welds shall be inspected similarly as for the fillet weld test, especial attention being given to the locations where compound or rewelding has been done.

Macro-Etching

The specimens for macro-etching are prepared by grinding or filing until the surface is flat. Then the grinding or polishing should be continued on successively finer abrasive wheels or grades of emery paper. Each grinding should remove the scratches left by the previously used coarser wheels. The final polishing should be with No. 1 emery paper.

A saturated solution of ammonium persulphate should be used for the etching. It may be supplied with a small cloth or wad of cotton. When the etching is finished, hold the specimen under running water and rub with a cloth or cotton, then wash with alcohol and dry quickly.

The etched specimen may be inspected for the following:

Thoroughness of penetration of the welding.

Contour of weld.

Fusion between weld metal and base metal.

Freedom from cold shuts, blowholes and non-metallic inclusions.

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